AN EVALUATION OF THE IMPACT OF INTRODUCING A BREAKFAST CLUB ON NUTRITIONAL STATUS AND COGNITIVE FUNCTION IN LOWER SOCIAL CLASS PRIMARY SCHOOL CHILDREN.

Shilpee Mehrotra, BSc (Hons), MMedSci

Thesis submitted to Queen Margaret University College for the degree of Doctor of Philosophy

Department of Dietetics, Nutrition and Biological Sciences,
Clerwood Terrace, Edinburgh, EH12 8TS

May, 2005

For Mataji and Pitaji

The future belongs to those who believe in the beauty of their dreams.

Eleanor Roosevelt

List Of Contents

Cross Sectional Analysis

Chapter 3.1

Chapter 3.2

Chapter 3.3

Longitudinal Analysis

Chapter 6.1

Chapter 6.2

Chapter 6.3

Chapter 6.4

List of Tables

Chapter 4.3

Chapter 6.1

Chapter 6.2

List of Figures

Chapter 3.3

Chapter 3.4

Chapter 4.2

Chapter 6.1

Chapter 6.4

Chapter 7.2

Abbreviations

% body fat	percentage body fat
% energy	percentage energy
% energy	percentage energy
% RNI	percentage reference nutrient intake
± Std.	Standard Error Mean
5-HT	sertonin
ANOVA	analysis of variance statistical test
ATP	adenosine triphosphate
BC	Breakfast Club Group
BC SCH	Breakfast club school
BC20	Breakfast Club 20 Group
BC20	Breakfast Club 20 Group
BIA	bioelectrical impedence analysis
BMI	body mass index
C.S	Cross-Sectional Study
Ca	calcium
CCK	cholecytokinin
CHO	carbohydrate
CNS	central nervous system
COMA	Committee On Medical Aspects of Food Policy
data 2	data collection 2
data 3	data collection 3
data 4	data collection 4
DEFRA	Department of Environment Food and Rural Affairs
DEXA	dual energy x-ray absorptiometry
DoH	Department of Health
F	female
FDI	Freedom from Distractibilty
Fe	iron
FFA	free fatty acids
FFM	fat free mass
FM	fat mass
g	grams
Gc	Crystallized Intelligence
Gf	Fluid Intelligence
Gq	Quantitative Thinking
Gs	Broad Speediness
Gv	Broad Visualization
H	body height
HDL	high density lipoprotein
IDDM	insulin dependent diabetes
IQ	Intelligence Quotient
Kcal	kilocalories
kg	kilograms
L.S	Longitudinal Study
LDL	low density lipoprotein
LNAA	large neutral branched-chain amino acids
m	metres
M	male

MAFF	Ministry of Agriculture Fisheries and Food
mg	milligram
mls	millilitres
mmol	millimols
MUFA	monounsaturated fatty acids
NANCE	National Advisory Committee on Nutritional Education
NB SCH	Non Breakfast Club School
NBC	Non Breakfast Club Group
NBC20	Non Breakfast Club 20 Group
NPI	New Policy Institute
NIDDM	non insulin dependent daibetes
PUFA	polyunsaturated fatty acids
RDA	recommended daily amount
RTEBC	Ready-to-eat-breakfast cereals
SAR	Short-Term Acquisition and Retrieval
SBPSchool	Breakfast Programme
SFA	saturated fatty acids
TBW	total body water
TRP	tryptophan
ug	microgram
Vit B12	cobalamin
Vit B6	pyroxidine
Vit	vitamin
Vitamin B1	thiamin
Vitamin B2	riboflavin
W	body weight
WI	weighed inventory
WISC-III	The Wechsler Intelligence Scale for Children
WISC-III	The Wechsler Intelligence Scale for Children-Revised
WISC-III^{UK}	The Wechsler Intelligence Scale for Children –Third Edition UK

Acknowledgements

I would like to thank my director of studies Michael Clapham, Lecturer in Nutrition for his help, enthusiasm and encouragement throughout the study. I would also like to express my sincerest gratitude to Dr Isobel Davidson who despite supervising the research at a later stage has been an invaluable guide for writing-up and completing the thesis. I'd like to show my appreciation also to Mr Don Sutherland for his drop of a hat statistical support . Thanks to Dr Vivienne Chisholm for her psychological advice.

I'd like to extend my appreciation to Queen Margaret University College for funding the studentship. Thank-you also to The Kellogg Company for helping out with funding in the final stage and to my colleagues there for understanding my madness.

Special thanks to the girls in room 416 and especially to Paula R for 4 years of comradely spirit and to my home friends for trying to keep me relatively sane. Cheers also to Ken for sorting out all my p.c panics.

Most importantly, my most heartfelt appreciation is for my wonderful parents. I feel tremendously lucky, proud and honoured to have had their complete backing and unfailing love and support in a year that changed me forever. I will never forget how in their own special ways they breathed life into their weary daughter every weekend of the last year so that she could write and complete one of her dreams.

Mataji , your love, patience and culinary arts have fed body, mind and soul. My nutrition knowledge is nothing compared to your Professorship in good food.

Pitaji , your ever listening ears, careful words of advice, inspiring wisdom, absolute belief in me and proofreading has been a godsend. You have been and will always be my greatest mentor.

I can never thank-you both enough but I shall try and promise that there will be no more drama.....

Signed Declaration

This thesis has been composed and written entirely by myself and has not been submitted previously for any other degree.

Signed:.....

Date:.....1/05/05.....

Abstract

Breakfast has been shown to increase the supply of glucose to the brain which improves short-term memory. On waking hepatic glycogenolysis is the major buffer against short-term (12-18 hrs) fasting. The higher ratio of brain weight to liver weight in the child (1.4 - 1.6 versus 0.73 for the adult) and the 50% greater metabolic rate per unit brain weight in the child, places a greater demand on the child's glycogenic stores during a short fast as compared to the adult. Few school breakfast studies have examined the effect of different breakfasts on cognitive performance.

This study investigated the nutritional differences of a habitual breakfast consumed at home (NBC) and breakfast served at a breakfast club in (BC) school and the effect of these breakfasts on cognitive performance. Subjects were primary school children aged 7-11 years old in Scotland. When baseline cognitive performance scores were compared to scores at data collections 2,3 and 4 there were more significantly pronounced improvements for the NBC group than the BC group ($p \leq 0.001$). There were significantly greater numbers of children eating a cooked breakfast in the BC group and significantly higher numbers of children eating a cereal breakfast in the NBC group. As a result breakfasts of the BC group were higher in fat (MUFA and PUFA) ($p \leq 0.01$) and lower in percentage energy from carbohydrate than the NBC group. Positive correlations existed between percentage energy from carbohydrate and percentage energy from starch and cognitive test performance ($p \leq 0.01$) This suggests that a breakfast higher in % energy from carbohydrate such as a cereal breakfast benefits short-term memory , by supplying the brain with readily available supply of glucose it's primary and preferred fuel.

This results of this research provide evidence for the requirement of guidelines to ensure that breakfasts served at school will both assist learning in morning lessons and be in-line with healthy eating recommendations.

Chapter 1

Introduction

1.1 The Breakfast Meal

Breakfast is popularly considered to be the most important meal of the day, yet is it often the smallest in size of the 3 main meals and one that is frequently missed. Its importance lies in the fact that it 'breaks the fast' after sleep and is therefore viewed as a refuelling meal and one that 'kick starts' the day. During sleep the body transcends from the fed to the fasted state as serum insulin concentrations fall and serum glucagon concentrations rise. The liver must begin glucose production during this time and will continue until about one-half of the glycogen stores are depleted. On waking hepatic glycogenolysis is the major buffer against short-term (12-18 hrs) fasting. In children the brain accounts for more than 50% of body oxygen consumption (Sokoloff, 1976). The higher ratio of brain weight to liver weight in the child (1.4 - 1.6 versus 0.73 for the adult) and the 50% greater metabolic rate per unit brain weight in children therefore places a greater demand on glycogenic stores during a short fast as compared to the adult. The child's relatively small muscle mass in turn limits the availability of glucogenic amino acids for hepatic gluconeogenesis. It is at this time therefore that breakfast is vital in reducing the reliance on fat oxidation and to provide the fuel for preferential oxidation of glucose. Childhood is also a time of rapid growth where nutrient intake should reflect the increasing demand for energy, vitamin and minerals as the building blocks for muscular and bone growth. It is apparent therefore that breakfast is an especially important meal to this group for both re-fuelling in the morning and ensuring an adequate intake of nutrients.

Mornings in most households are rushed and as a result breakfast consumption in children is on the decline in terms of the percentage of children eating breakfast and in nutrient quality in those that do (Street and Kenway, 1999). Most children eat something in the morning although whether this can be considered to be 'breakfast' lies in the question of

what actually defines this meal. Is any food or drink consumed in the morning breakfast or should breakfast provide a minimum amount of calories and nutrients?

Investigators in the U.S have proposed that an ideal breakfast should provide at least 25% of the recommended daily energy intake and 25% of the RDA for protein (Morgan *et al.*, 1981).Advice given by health professionals in the United Kingdom is that a breakfast should constitute 20% of the Recommended Nutrient Intake (RNI) of energy, macronutrients and micronutrients (Gibson and O'Sullivan, 1995). It is also recommended that a healthy breakfast should be high in carbohydrate and low in fat (Street *et al.*, 1999). Regular breakfast as a healthy dietary habit should be established in early childhood since eating patterns appear to track from childhood until late adolescence (Baric *et al.*, 2001). However a significant minority of children in the U.K are arriving at school either having omitted breakfast or eaten, crisps confectionery and fizzy drinks (Street *et al.*,1999).

1.1.1 Breakfast Skipping

Several studies have illustrated breakfast skipping in children (as depicted in table 1.a). Whilst this list is not exhaustive, missing breakfast is evident even in children as young as 5 years. Missing breakfast in children increases with age whilst the habit is established once again when they become adults and have offspring themselves (Family Food Panel, 2004).

Table:1a The Percentage of Children Skipping Breakfast World Wide

Study	Country	Age Group (years)	% Children
Baric *et al.*, 2002	Croatia	10	1.7
NPI, 2000	U.K	4-18	17
Nicklas, 2000	U.S	15	37
Gardner and Merchant, 1998	U.K	8-16	6
		15-17	30
Gardner and Merchant, 1996	U.K	8- 15	6
Box and Landman, 1994	England	5-8	5
Ruxton *et al.*, 1996	Scotland	7-8	6
Ortega *et al.*, 1996	Spain	9-13	5
Nicklas *et al.*, 1993	USA	10	16
Curry and Todd, 1992	Scotland	11-15	38
Zabik, 1987	U.S	5-12	6

Up to 17% of British school children leave home in the morning without anything to eat (United Kingdom Consumption Study, 1998). Figures from Gardner Merchant 1996, school caterers survey on 400,000 pupils, indicate that 18% of the 15-16 year old girls surveyed, 12% of the boys of the same age, miss breakfast (Gardner and Merchant, 1998). In a 2000 study 23% of boys and 14% of 15-year old girls skipped breakfast (Nicklas *et al.*, 2000). A recent study among children and adolescents in Croatia showed a much smaller percentage of 1.7% (Baric *et al.*, 2002). In a 1985 survey of Appalachian adolescents, reported that 32% and boys and 39% of girls skipped breakfast (cited in Skinner *et al*, 1995). Siega-Riz *et al.* (1998) indicated a significant decline in breakfast consumption in the U.S between 1965 and 1991 for children aged 1-18, with consumption decreasing in children aged 8-10 years by 9 % and in adolescents by 13-20 %. Researchers in Southampton in the U.K, found that 5 % of 5-8 year old omitted breakfast (Box & Landman 1994) and the School Health Service reported that 7% of 11 year-olds and 12% of 13 year olds missed breakfast in Hampshire. In Scotland Curry & Todd found that only 62% of 11-15 year olds took breakfast every day and 20% took it once weekly. An Edinburgh study in 1996 reported that 6% of 7-8 year old omitted breakfast on a regular

basis (Ruxton *et al.*, 1996). One Spanish study found that 5 % of 9-13 year-old children missed breakfast regularly (Oretga *et al.*,1996).

In general , studies of breakfast consumption fall into two groups : (1) those that focus on whether breakfast is eaten, and (2) those that examine the effects of eating breakfast on various performance measures (Devaney and Stuart 1998). The phenomenon of breakfast and performance has been an area of interest since the 1940s. Whilst it is generally excepted that the morning meal does have an effect on some aspects concentration, memory and behaviour some of the evidence is conflicting and the methodology behind this body of research is not robust. The studies which examine breakfast consumption typically use the broader definition of any food or beverage consumed between waking up and the late morning hours. Studies which examine the impact of breakfast on behaviour or performance measures typically use a more rigorous definition based on some minimum calorie content or the number of foods and/or food groups consumed.

1.1.2 Impact of Socio-Economic Status on Breakfast Consumption

Several studies find that breakfast skipping varies by socio-economic characteristics. Golding *et al.*, (1984) found that skipping breakfast is more common in children whose fathers are manual than in non-manual occupations.). In the U.S a study of low-income elementary students estimated that up to one-fourth of low-income children went to school without having had breakfast (Sampson *et al.*, 1995). The Child and Adolescent Trial for Cardiovascular Health (CATCH) data revealed that 11 % of Hispanic students and 8 % of African American students skipped breakfast, compared with none of the Asian American students and 4 % of Caucasian students (Dwyer *et al.*,1998). Data from the Bogalusa Heart Study also showed that more blacks (24%) than whites (13%) skipped breakfast (Nicklas *et al.*, 1998). In the longitudinal study by Siega-Riz *et al.*, (1998), children in-single parent households, in households with incomes greater than 350 percent of the poverty index, and in families with fewer than three members were less likely to consume breakfast than children than children from dual-parent households, with lower-income and

larger family size. Eating breakfast was associated with a female head of household with at least a college education. If the female head of household was employed outside the home, the likelihood of eating breakfast decreased. The downward trend in breakfast consumption may be attributable to the change in demographics, for instance, an increasingly large number of women are now working, there has been an increase in divorce rate and the proportion of out-of-wedlock births have increased over the last 30 years. These changes have led to a greater number of single-parent households with female heads of households and to a larger proportion of children living in poverty. Also a growing number of children are responsible for preparing their own meals. Ruxton *et al.* (1996) in their research into the diets of 136 primary-schoolchildren in Edinburgh did not find an association between social class and breakfast omission in 7-8 year olds, however they did find a lower energy and nutrient intake at the breakfast meal in low-compared with high-social class children. Gardner and Merchant found that only 4% of socio-economic grades A and B have no breakfast whereas this doubles to 8% amongst socio-economic grades D and E (Gardner and Merchant, 1998). Canadian researchers Chao & Vanderkooy (1989) found that economically disadvantaged urban children skipped breakfast more than their more affluent counterparts.

Published government statistics show that one in 3 children live in poverty (Nelson 2000). This figure is representative of the number of children living in households where income is less than half of average earnings. They found that 23% of two parent households live in poverty despite the fact that many are in employment. Indeed 59% of lone parents live in poverty with the great majority on Income Support (Government Statistical Service, 1996). Poverty which is as widespread as this will have detrimental affects on the nutritional status of a significant number of children. The National Food Survey (Department of Health (DoH), 1989) showed that consumption was higher for bread (particularly white bread), eggs , potato ,chips ,baked beans and sugar, and lower for milk, carcass meat chicken and fruit. Nutrient intakes were consequently lower for B-carotene

equivalents and vitamin C. Other survey data (Dowler and Clavert, 1995; Ruxton and Kirk, 1996) suggest that children of families from lower social classes have lower intakes of Fe, Ca, folate and other nutrients. Scottish primary-school children are also viewed as a nutritionally at risk group and have been described by the Scottish Office (1993) as having 'an inappropriate diet' and 'unhealthy eating patterns'.

1.2 The Diets of British School Children

Whilst there is much interest and concern regarding the diets of British school children, there is a relatively small amount of scientific research in this area, especially for primary school aged children. The problems of measuring food intake in children (to be discussed in section 1.2.2) is a possible reason for the amount of information available. The Surveys of the diets of British school children have been discussed below.

1.2.1 Surveys of the Diets of British School Children

Widdowson in her 1947 study of 1000 children found that the diets of some school children and particularly those who were from a less privileged backgrounds were inadequate. Cooks *et al.* (1973) study showed that there were low energy intakes for children aged 8-11 years and 13-15 years compared to the Recommended Daily Intakes (RDI) (Department of Health and Social Security (DHSS), 1969). Energy intake was related to weight, but Durnin *et al.* (1974) showed that heavier children ate less than their leaner counterparts. Overweight people however are likely to under-report intake (Black *et al.*, 1991).

A Northumbrian study which looked at nutritional intake and the height and weight of 11-12-year olds in 1990 compared with information obtained in 1980 showed that nutrient intakes fell over time for boys but not for girls (Adamson *et al.*, 1992). Fe and vitamin C (vit C) increased for both sexes, and nutrient density of the diet improved for all sex and social class groups. Payne and Belton looked at the diets of pre-school children in Scotland using a 7 day weighed inventory (WI) method (n=153). They found that energy intakes

were close to estimated average requirements , whilst some children were below the RDA for vitamin A (vit A) , vit C, iron (Fe) and calcium (Ca) (Payne and Belton, 1992).

The Scottish diet has been an area of concern for many years and many schemes have been set up to improve nutritional intake in this country. Anderson and Lean looked at a nutrition based education programme in the Grampian area in order to ensure the adoption of the nutritional principles outlined in the 1983 NACNE and 1984 COMA (Committee on the Medical Aspects of Food Policy) reports (Lean *et al.,* 1988). Since the 1993 Scottish-Diet Report (1993) , the Scottish diet has been under heavy scrutiny. The report revealed that children were following a diet similar to that of Scottish adults, which was one that was high in fat, and low in vegetables of all kinds. It quoted that

' the usual Scottish diet consumed by children is also that which would now be conducive to the development of adult chronic disease.'

Although it has been 10 years since this report was written very little has changed and this group is still vulnerable. Anderson's research into dietary patterns in adolescents in the West of Scotland show that this group have higher fat, higher sugar diets than healthy recommendations (Anderson *et al.,* 1994). A survey that looked at the diets of 12 year olds in Scotland (n=61) in Scotland found that fat and sucrose intakes were in excess of the NACNE 1993 recommendations. Cresswell's Glaswegian study of 270 girls also revealed this finding (Cresswell *et al.,*1983).

The diets of over 300 Tayside children aged 11-12 years were compared with the targets set by the Scottish Diet Report (1993) and it was found that less than 2 % achieved all of the first five targets, namely 3-4 portions of fruit and vegetables per day; whole grain or granary bread or cereals twice daily: semi-skimmed milk; fish twice weekly; and meat products less than twice weekly (Wriden and Moore, 1995). A 2001 study looking at the dietary habits of children in Tayside found that less than 5% were eating targets set by the Scottish Diet Report (Wrieden *et al.,* 2001). It is generally agreed that an increased consumption of vegetables and a reduction in fat will, on a population basis, help to

reduce the incidence of chronic diseases such as coronary heart disease (CHD) and cancers (MacMahnnon, 1992). The link between high SFA intakes with CHD (WHO, 1990) coupled with the fact that several epidemiological studies have shown tracking of CHD factors (e.g. plasma lipids and blood pressure) from infancy into adult life (Boreham *et al.*, 1993, Lauer *et al.*, 1988, WHO, 1990) provide evidence that children's eating habits are of prime importance. In fact recent evidence show the laying down of fat and hardening of the arteries in children as young as 12 years of age (Olson, 2002).

Targets were set out to improve the diets of the Scottish population including school children for the year 2005. Whilst there are standards for school lunch which have been set (Scottish Executive, 2003) there is no such policy for school breakfast.

Whilst Benton and Roberts (1988) and Nelson *et al.,* (1990) are two other notable studies which looked at the diets of school children (and mental performance) there is an even smaller pool of data on Scottish school children which include studies of McNeill *et al.,* (1991), Payne and Belton (1991), Ruxton *et al.,* (1996), and the Department of Health (DoH, 1989).

In 1989 a report on the diets of British School children was complied by the DoH from data collected by 2 697 school aged children aged 10-11 and 14-15 years old (DoH, 1989). A 7 day WI was used to measure dietary intake an weight and social class were also collected. There was no detriment to growth since height and weight were above the 50^{th} percentile when compared to UK population standards despite that fact energy intakes were approximately 90% RDA. Riboflavin (B_2) and Ca were below the RDA and for girls especially. Protein intake, thiamine, nicotinic acid and vit C were above the RDA for all groups but Fe intake was low for girls. The 974 children in the Scottish sub-sample (n=974) ate less vegetables and they had lower vit C, beta carotene and they also had lower retinol intakes.

The most recent survey to look at the diets of young people was the research commissioned jointly by the Ministry of Agriculture, Fisheries and Food (MAFF) and

DoH and was published in June 2000. This survey is the National Diet and Nutrition Survey (NDNS) and is the largest survey of its kind undertaken in the young British population (Gregory *et al.*, 2000). There were 1701 young people aged 4 –18 years old who provided a 7-day weighed dietary record. 56% of the children also provided blood sample for nutritional status and body measurements were also taken for 90% of the sample.

Whilst mean energy intakes were below the EAR, these low values of energy intake may have been partly explained by under-reporting. In fact a feasibility study conducted for this survey identified that under-reporting can be a problem when assessing the diets of 4-18 year olds (Smithers *et al.*, 1998). Whilst energy intakes in this survey were also lower than in the 1983 survey of school children (DoH, 1988) the authors concluded that actual energy intakes were adequate since the children were taller and heavier in the NDNS. The proportion of energy from fat was close to the daily recommended value (DRV), as was total carbohydrate (CHO). However non-milk extrinsic sugars were found to be above the 11% DRV. Ca and Fe were revealed as problem nutrients for key age groups. In fact 45% of girls aged 11-18 years old had Fe intakes below the LRNI (Gibson and Ashwell , in press) and 70% of 11-14 year olds were not consuming enough Ca. The results from the present study have been compared to the NDNS in chapter 3.4 and 6.4.

Ruxton in her study of 136 Edinburgh 7-8 year old school children commented 'that most dietary surveys concentrate on adolescents, leaving a 'gap' between the ages of 5 and 9 years. Apart from data on forty-nine 7-10 year olds from the Nelson *et al.*, (1990) study there has been no focused dietary survey on this group since 1973.' (Ruxton *et al.*, 1996). In the last 7 years the National Food Survey and the National Dietary and Nutrition Survey (NDNS 2000) has taken place but part from these studies and the present research into 7-11 year old Edinburgh school children there has been no further medium to large studies carried out.

Ruxton compared her results to the UK dietary reference values (DRV) (DoH, 1990) for energy, macronutrients and micronutrients. Whilst energy intakes were close to the estimated average requirement (EAR), the percentage (%) energy from fat and saturated fatty acids (SFA) was higher than the DRV. The % of food energy from total CHO was close to the DRV but starch was below the DRV and sugars were above (Ruxton *et al.*, 1996). Most micronutrient intakes were above the RNI. The results of Ruxton's work and the present study have been discussed in chapters 3.4 and 6.4.

1.2.2 Measuring Dietary Intake in School Children

The accurate and precise measurement of dietary intake in human studies is a topic that has been addressed many times in nutritional and dietetic research . There are many methodologies that have been shown to collect dietary information to varying degrees of accuracy. Garrow (1974) observed that " the measurement of the habitual food intake of an individual must be among the most difficult take a physiologist can undertake." Measurements of food intake can be retrospective namely the 24 hour recall method, diet history and food frequency questionnaire. These methods have been used extensively in large scale studies (Morgan *et al.*, 1978, Blom *et al.*, 1989). One major advantage is that this method is quick inexpensive and non-invasive. The drawback being the subject has to recall the food eaten and estimate a portion size consumed.

Prospective methods are the weight and estimated food records. In this method the subject has to record food and drink eaten over a period of time. For the weighed inventory method the food is weighed on scales, whereas the estimated food dairy describes the food in terms of household measures.

The method which is often described as the most accurate way of measuring usual food intake remains the weight inventory method, originally developed by McCance and Widdowson in the 1930's (Marr 1971, Bingham 1987, Bingham 1988, Borrelli 1990, Livingstone *et al.*, 1990). This method however is time-consuming and impractical (Acheson, 1980) and has been described as needing close supervision (Todd *et al.*, 1972).

Whilst one of the major advantages to this method is that there is a loss of the error due estimation of portion sizes Todd et al (1983) found only marginal difference in the estimated and weighed methods.

The weighed method is invasive and may result in a false representation of intake because of alterations in eating behaviour. This method is not suitable for children unless they are supervised by parents, teachers or the researcher themselves. Under-reporting is a major issue in dietary methodology (Bingham, 1987, Macdarmid and Blundell, 1998; Livingstone , 1995; Black *et al.,* 1997). In a study which compared energy intakes to estimated energy expenditure by doubly labelled water clearly showed under-reporting in adolescent and post-adolescent children in the 7 day WI (Livingstone *et al.,* 1992).

The estimated food diary is a variation to this method which whilst still requiring some degree of motivation is less taxing than the weight inventory method. The estimation of food portions can be transformed into grams of food by using published standard food portion sizes.

The limitations of estimated food record are introduced from the subject bias, miscalculation of food portions over and under-reporting. Errors may also be introduced by the investigator in converting portions into grams and the quality of the conversion food tables used. Errors by the subjects can be reduced by giving clear verbal and written instructions to the subjects (Bingham *et al.,* 1994). Several studies have compared calculated nutrient intakes from an estimated record to that of a weighed record (Cade 1988, Edington *et al.,* 1989, Ralph *et al.,* 1990). A difference of less than 10% for all nutrients was found except for fibre and vit A (Cade, 1988).

Whilst the estimated intake is less accurate than a weighed intake, it is a simple and sufficiently accurate means of measuring energy and nutrient intake Bingham 1987, Cade, 1988, Edington 1989, Ralph 1990).

Whilst observation methods provide interesting possibilities for obtaining more accurate dietary assessment of children by avoiding errors of recall (Simons-Morton *et al.,* 1991), it is expensive and time-consuming and the mere fact that you are observing may change the childrens' behaviour you are trying to measure. Self-report is necessary even when measuring dietary assessment among children which reflects cognitive processes (Shafter 1985). The cognitive processes that are needed are attention, perception, organisation, retention retrieval and response formulation (Baraowski and Domel , 1994).There are may considerations when children are the target population of dietary surveys. Self-reported food intake requires all the processes listed above. From the age of 8 years there is a rapid increase in the ability of children to self-report food intake (Livingstone and Robson, 2000).

There are routes of error at all of these stages and one common problem in children is overestimation. Knuiman *et al.,* (1987) found that records by 8 or 9 year old boys overestimated school lunch by 20-30% compared with duplicate portions collected by observers. The main differences were in common main course items, such as potato, meat and fish whereas there were virtually no differences in bread and milk (which came in standard portions at school). Van Horn *et al.,* (1990) also found that children over reported servings from various food groups.

In order to aid food portion size estimation food photographs have been used in adults to effectively estimate nutrient intake (Robson and Livingstone 1999). The use of the photographic method in children has been less conclusive especially since the portion size photographs available at the time of the current research were for adults only. However it may still be a valuable tool if the % error of estimation can be calculated by an observer.

An estimated dietary diary must measure a number of days and the magnitude of this is important since as the days are increased, the demand on the subject also increases and hence compliance may decrease (Livingstone *et al.,* 1990). This is obviously a consideration when measuring intake in children.

Taking all of the above into consideration in the present study a 3 –day estimated diet dairy was completed 4 times over the course of the school year. It was felt that compliance would reduce if the measurement period was increased. The difficulties of measuring intake via this method is discussed further in the discussion section.

1.3 School Meals

School lunches and their nutritional value has warranted updated guidelines over the years since earliest standards were introduces as early as 1955 (The Ministry of Education 1955). Although the Education Act 1980 removed the obligation for schools to provide meals of a set nutritional standard, the government recognised the importance of the contribution that school lunches can make to the health of school children and re-introduced regulations on national minimum nutritional standards for schools who opt to provide lunches.

The proportion of the daily nutrient provision that should be achieved from a single daily lunch has been extensively reviewed by the Caroline Walker Trust Expert Working Group on School Meals (1992), the outcome of which were the Nutritional Guidelines for School Meals. These Guidelines cover the nutrients and micronutrients (vitamins and minerals) currently of most concern in school children's diets and remain largely appropriate for calculating the nutrient standards for Scottish school children

The Caroline Walker Trust (1992) suggested that school lunches provide : a minimum of 30% Estimated Average Requirement (EAR)of energy(World Health Organization Recommendations on Diet, Nutrition and the Prevention of Chronic Disease 1990) 35% Reference Nutrient Intake(RNI) of calcium, 40% RNI FE and 30% Vit A, 35% RNI of vitamin C, a minimum NSP content of 30% Reference Value and not more than 11% added sugars. Energy should be made up of not less than 50% carbohydrate, 30% protein and not more than 35% fat . sodium provision should be no more than 30% of the Dietary Reference Value (SACN, DoH, 2002).

On the 1st of April 2001 compulsory nutritional guidelines were set across England and Wales and school lunch guidelines were also developed for Scotland and Northern Ireland. In England and Wales the regulations for lunch are based on the Balance of Good Health plate model (see figure 1.b below) whereby every school lunch should provide :

- a portion/portions from the bread , potato, rice and pasta food group. Starchy foods cooked in oil or fat should not be served more than three times a week.
- Fruit and vegetables must be available every day. Fruit based puddings must be available twice a week.
- A portion/portions from the milk and dairy food group.
- A portion/portions from the meat, fish and alternative group. Red meat must be served at least twice a week . Fish must be served at least once a week. Cheese may be available in this group.

If foods containing fat and sugar are available, they should form no more than 10% of the total food offered (from www.dfes.gov.uk/schoollunches).

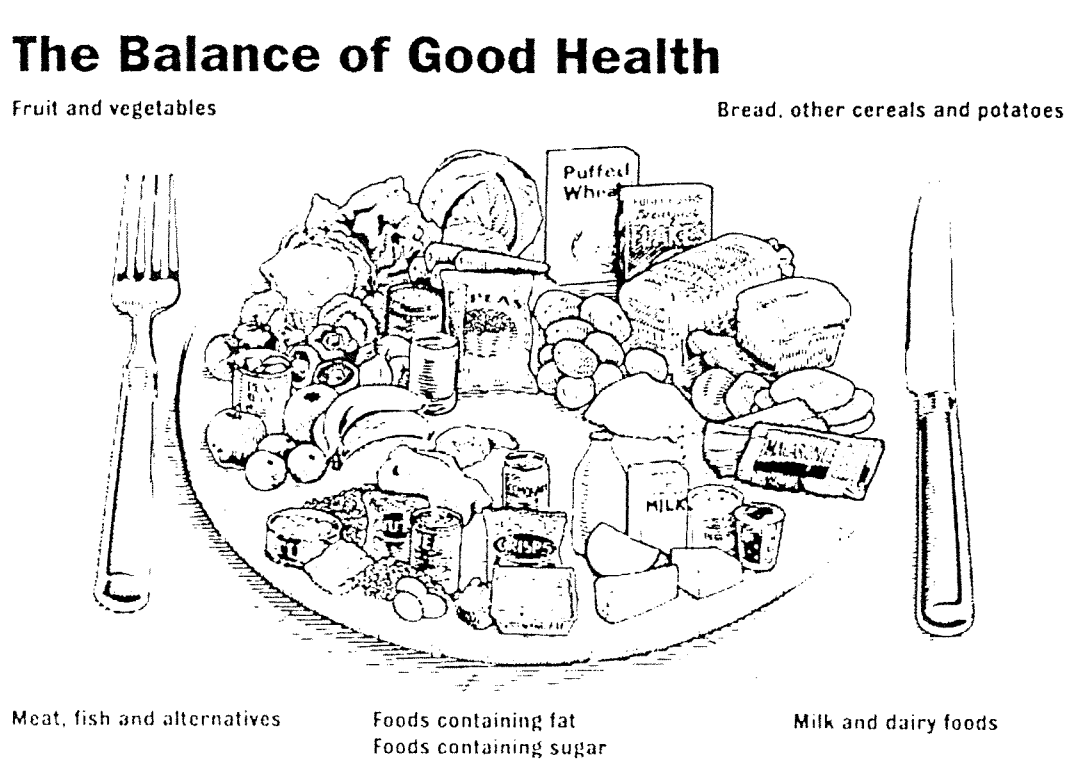


Fig:1.a The Balance of Good Health (Health Local Authority, DoH and MaFF, 1994)

1.3.1 Nutritional Standards for School Meals in Scotland

In January 2002, Scottish Ministers established an Expert Panel on School Meals to make recommendations that would form the framework of a national strategy for school meals. The Panel's remit was to provide recommendations and a fully developed implementation strategy to:

- establish standards for school meals
- improve the presentation of school meals to improve general take-up
- eliminate any stigma attached to taking free school meals.

In February 2003, Hungry for Success, the report of the Expert Panel on School Meals, was published. This report sets out the Panel's vision for a revitalised school meals service in Scotland and presents a number of far-reaching recommendations connecting school meals with the curriculum as a key aspect of health education and health promotion

(Scottish Executive, 2003). Ministers have announced their acceptance of all the Panel's recommendations including the national nutrient-based standards for school lunches. These standards are the first of their kind in the UK. They form a key part of the Scottish Executive's campaign to improve Scotland's health record by improving the nation's diet. Achieving the standards in all primary and special schools are set for December 2004 and in all secondary schools by December 2006. The Health Education Board for Scotland developed Eating for Health as a model for healthy eating in Scotland in 1996. In England the equivalent model, the Balance of Good Health (shown in figure: 1.a above), was developed in 1994 by the Health Local Authority, DoH and MAFF. The nutritional guidelines that have been set for primary school children in Scotland are outlined in table: 1.b on the next page.

Table 1.b: Nutrient Standards for School Lunches for Pupils in Primary Schools

			Unit	Infants 5-6 years	Juniors 7-10 years
Energy	30% of EAR[1]		MJ/Kcal	2.04 MJ	2.33 MJ
	Mean of girl and boy			489 Kcal	557 Kcal
Fat	Not more than 35% of food energy	Max	g	19	21.7
Saturated Fatty Acids	Not more than 11% of food energy	Max	g	6	6.8
Carbohydrates	Not less than 50% of food energy	Min	g	65.2	74.3
NME (non-milk extrinsic) Sugars[2]	Not more than 11% of food energy	Max	g	14.3	16.3
Fibre/NSP (non-starch polysaccharides)[3]	Not less than 30% of calculated	reference value Min	g	3.9	4.5
Protein	Not less than 30% of RNI[4]	Min	g	5.9	8.5
Iron	Not less than 40% of RNI	Min	mg	2.4	3.5
Calcium	Not less than 35% of RNI	Min	mg	158	193
Vitamin A (retinol equivalents)	Not less than 30% of RNI	Min	µg	150	150
Folate	Not less than 40% of RNI	Min	µg	40	60
Vitamin C	Not less than 35% of RNI	Min	mg	11	11
Sodium	Not more than 30% of RNI	Max	mg	180	360
Fruit and vegetables	1/3 of 5 portions per day		Portions	2	2

[1] Estimated average requirement
[2] These are added sugars rather than the sugar that is integrally present in food (e.g. table sugar, honey, sugar in fruit juice and soft drinks)
[3] Here calculated as 8g per 1,000 kcal
[4] Reference nutrient intake

(Scottish Executive, 2001).

1.3.2 Guidelines For Breakfast Served at School

As yet there are no nutritional guidelines in England or Scotland for breakfast served at school. Health professionals recommend that breakfast provides 20% of the RDA for

energy and nutrient for adults and children alike (Gibson and O'Sullivan, 1995) but this has not been implemented as policy for breakfast provision in breakfast clubs at school. School breakfast programs (SBP) breakfasts in the U.S are required to required to provide approximately one –fourth of the RDA for important nutrients over a period of time (protein, ca, Fe, vit A, vit C and calories). In addition regulations now require that all school meals meet the recommendations of the 1995 Dietary Guidelines for Americans[1].

To achieve both the RDA and the Dietary Guideline standards, schools may use several methods for planning menus. One way is to prepare meals using food-based menu planning. A school breakfast using the food-based menu planning approach must contain , at a minimum, the following food components:

- A serving of fluid (whole or low fat milk served as a beverage or on cereal or used in part for each purpose

- A serving of fruit and vegetable or both, or undiluted fruit or vegetable juice

- Two servings from one of the following components – bread/bread alternative or meat/meat alternative: alternatively, there can be one serving from each component.

Whilst there are no definite guidelines for breakfast provision at school in the U.K at present, it is one of the aims of the present research to present the case for the need for nutrient standards at breakfast and recommendations for these based on scientific evidence.

[1] The applicable recommendations of the U.S Dietary Guidelines are (1) eat a variety of foods (2) limit total fat to 30% of calories (3) limit saturated fat to less than 10% of calories (4) choose a diet low in cholesterol (5) choose a diet with plenty of vegetables, fruits and grain products (6) use salt in moderation and (7) eat a diet rich in fibre.

1.4 Improving The Diets of Scottish School Children

The Scottish Diet Action Plan highlighted a need for improved nutrition in Scottish schoolchildren (Scottish Office, 1997). The government set out an ambitious agenda for improving many areas of children's lives (Street and Kenway, 1999). On the health front targets included tackling the inequalities in health amongst children, improving the nutritional status of their diets in order to reduce escalating rates of anaemia, dental caries and obesity, and eradicating poverty (Acheson, 1998). The Department of Health's Healthy Schools Programme was an important national initiative for all of these issues and as part of this remit Health Boards in Scotland set out to better the nutritional status of school children by the opening of breakfast clubs countrywide. Breakfast clubs were also proposed to have an effect on the educational arena, by boosting children's academic performance from the notion than a less hungry child is more likely to concentrate and learn and also by reducing the rates of school absenteeism (Ball, 1998). Encouraging a more holistic approach to education was another important theme in the government agenda, the idea being that schools should develop much closer links with their local community and promote a 'whole school' approach to meeting, the health, education, social and emotional needs of children (Ball 1998). Breakfast clubs were also viewed as having an effect on childcare and hence on family support to assist parents or looking for work, and to reduce the numbers of 'latchkey' children.

Data from the Kid's Club Network database in 1999 suggested that at that time there were over 700 breakfast projects operating in the UK (Street and Kenway ,1999). At present this figure is estimated to be over 5000. Despite this great growth in breakfast clubs the amount of research and evaluation of how breakfast clubs effect children in the UK has been relatively small and many of the studies carried out have been small scale, quasi-experimental and have not looked at the school children over the school year.

The largest evaluation to date is one looking at 33 breakfast clubs that won awards in the 2000 UK National Breakfast Awards scheme (Harrop and Palmer , 2002), which is a product of a long standing collaboration between the New Policy Institute, Kellogg's and Education Extra. The study comprised two surveys of the winning clubs, undertaken at the start and end of the 2000/01school year respectively, plus more in-depth case studies during the year in 10 selected schools. Among these clubs, 19 were based in primary schools, 10 in secondary and 3 in special schools. 14 of the clubs were being established in 2000/01, and 19 were already running. Most of the 33 schools had a high number of children from disadvantaged backgrounds. The study was split into 4 main parts and questionnaires were given to the teachers, parents and children in order to gain an insight into how the breakfast club affected health and nutrition, education, children's social needs and parents and family life. The questionnaires which were intended for all the schools to complete in Autumn 2000 and Summer 2001 were pertinent but general and were not validated.. Many of the findings were based on case-studies which are of great interest in their own right but bear very little significance in the research community, and cannot be quantified to an extent that they can be used as scientific evidence to prove that breakfast clubs are beneficial for the health and education of children. If government policies are to be enforced then this type of evidence is required.

1.4.1 The Nutritional Contribution of Breakfast

Since there are so few findings on the contribution of the breakfast of breakfasts clubs to nutritional intake in children in Britain it is necessary to look at the nutritional benefits of breakfast *per se* and to also to look at breakfast feeding programs from other countries. Although studies of the nutrient effects of eating breakfast vary considerably in the study populations and data sets used, a consistent finding of these studies is that breakfast makes a significant contribution to nutrient intake over 24 hours. Livingstone (1991) reported a value of 6 % for Irish 5-9-year-olds, Magarey *et al.,* (1987) reported 20% for Australian 8-

year-olds, while Ruxton *et al.,* (1996) found a value of 14% for Scottish 7-8-year-olds. Spyckerelle *et al.,* (1992) found that breakfast supplied 16% of total energy in their 10-15-year-old French sample, a similar value to that reported for Spanish 9-13 year olds (Ortega *et al.,* 1996). In a deprived area in London Doyle *et al.,* (1994) found that breakfast provided only 3% of daily energy for 12-13-year-olds but this probably relates to the low intake of breakfast by this group (only 20% on a regular basis). A recent Croatian study showed that the energy intake from breakfast was 26% recommended daily allowance (RDA) (Baric *et al.,* 2000).

1.4.2 The Effect of Breakfast on Micronutrient intake

Devaney and Fraker (1989) were able to show that for children from the first National Evaluation of the School Nutrition Programs in the United States breakfast eating was significantly and positively related to the daily intake of all nutrients examined. Studies conducted by Zabik (1987), Nicklas *et al.,* (1993) and Sampson *et al.,* (1995) showed that children consuming breakfast had significantly higher total daily intakes of energy and nutrients when compared to those who did not and that breakfast skippers did not make up the difference in nutrient intake at other meals. Data from the Bogalusa Heart Study show that a large percentage of children who skipped breakfast did not meet two-thirds of the RDA for calcium, thiamine, iron, folacin, zinc, and vitamins A ,E ,D and B_6. The largest differences in nutrient intake between and breakfast eaters were for calcium, phosphorous, magnesium, riboflavin, vitamin B_{12} and A and folate (Nicklas *et al.,* 1998 and 1993; and Dwyer *et al.,* 1998).Morgan *et al.,* (1981) reported that 5-12-year-olds who regularly omitted breakfast had lower intakes of vitamin B_6, Fe, Ca, Mg, vitamin A, Cu and Zn compared with children who consumed breakfast cereals on a regular basis. A large percentage of children who skipped breakfast did not meet two-thirds of the RDA for calcium, thiamin, iron, folacin, zinc, and vitamin A, E, D and B_6. The largest differences in nutrient intake between breakfast skippers and breakfast eaters were for calcium, phosphorous, magnesium, riboflavin, vitamin B_{12}, and A and folate (Nicklas *et al.,* 1998

and 1993). The breakfasts of Australian pre-adolescent and adolescent (Magarey & Boulton, 1995) children provided a significant source of micronutrients such as Fe, thiamine and Ca. For Scottish primary schoolchildren Ruxton *et al.,* (1996) found that breakfast contributed 14% of energy and 9-36% of micronutrient intake to the overall diets. The contribution of breakfast to daily micronutrient intake was greater than the contribution to macronutrient intakes. The large contribution to overall intake for Fe, folate, nicotinic acid equivalent, thiamine and riboflavin, was most probably due to micronutrient fortification of ready to eat breakfast cereals (RTEBC). Children who ate RTEBC had overall diets which had a higher nutrient density and were lower in fat than those children who ate RTEBC less frequently or not at all. In an Irish study by McNulty *et al.,* (1996) researching 1015 schoolchildren aged 12-15 years found that those children who did not consume fortified breakfast cereals had daily intakes that fell below the lower reference nutrient intake for riboflavin, niacin, folate, vitamin $B_{12,}$ and also iron in girls. Baric *et al.,* in there 2000 study of breakfast quality differences in Croatia found that the highest micronutrient intakes at breakfast were of vitamin B_{12} and riboflavin (111.9 and 93% RDA respectively). According to the DOH of the UK (1991) 'cereal eaters' had higher daily intakes of a range of micronutrients and were more likely to have intakes which met British Reference Nutrient intakes.

1.4.2 Breakfast and Fat Intake

The relationship between breakfast eating and fat intake depends on the foods consumed at breakfast. Some traditional breakfast foods such as eggs, sausages, bacon and black pudding, are obviously higher in fat than breakfasts made up of lower-fat alternatives, such as RTEBC, semi-skimmed milk, yoghurt and fruit. Given the concerns about excess intake of fat, most of the studies carried out so far have concentrated on children's dietary intake of cereals. However other types of food are consumed at breakfast as children become more and more independent the likelihood of purchasing a 'breakfast' on the way to school has increased and this breakfast could be anything from crisps, chocolate, fizzy drinks and

sweets to a bacon or sausage roll purchased from outside the home. Whilst Ruxton *et al.* (1996) did report the different types of breakfast consumed by their sample of 136 Scottish primary schoolchildren 77.2% ate cereal,14.7% ate bread/toast only, 1.5% ate cooked and 6.6% confectionery, soup or milky drinks. In the Preziosi *et al,* (1999) study of breakfast type and daily nutrient intake and vitamin and mineral status in French children breakfast was divided into low-energy (<15% of the energy RDA), medium energy (15-25%) and high-energy (>25%), where high-energy breakfasts were associated with the consumption of RTEBC however the paper did not state what the non-RTEBC actually consisted of. The paper stated that high-energy breakfasts derived more energy intakes from carbohydrates and less energy from fat than those who consumed low-energy breakfasts. Similarly, cereal consumers derived more daily energy from carbohydrate and less energy from fat than did non-consumers. This finding was consistent with the observations of Schlundt *et al.* (1992). However there is some conflicting evidence proving that the percentage of energy from fat over 24 hours is lower from breakfast eaters than breakfast skippers (Dwyer *et al.,* 1998), while other studies found the opposite (Sampson *et al.,* 1995).

1.5 A Review Of Breakfast and Cognition Research

Research into how breakfast may affect performance goes back as long ago as the 1930s. and this very earliest research investigated behaviour and feelings of well-being. In the 1950s the Iowa Breakfast Studies carried out by Tuttle *et al.* (1949, 1950, 1952, 1954) were the first in a series of experiments which looked specifically at tests of mental performance. In the last 40 years there has been a plethora of research and it has been divided into 3 types. The studies have evaluated (1) the acute effects of breakfast omission on cognitive performance (2) the effects of school breakfast programs on cognitive and behavioural performance (3) the effects of glucose administration on cognitive performance. Before these studies are discussed it is important to describe what cognitive function is.

1.5.1 Cognitive Function

Cognitive function is the collection of higher processes that are carried out by the brain. These processes include long-term, short-term and working memory, attention, perception, problem solving and all other mental operations (Kandel *et al.,* 2000). Cognitive performance encompasses measures not only of speed (reaction time) but also of processing accuracy (measures of accurate and inaccurate detection).

Learning is the acquisition and storage of information as a consequence of experience and memory is a relatively permanent storage of this learned information. Depending on how long a memory lasts, it is designated as either working memory, a limited capacity, short term memory and immediate memory that lasts seconds to minutes, or long term memory which lasts for hours, days or years (Squire, 1987).

Most researchers agree that memory traces are laid down in neural systems throughout the brain and that different types of memory tasks use different systems. The release of neurotransmitters from pre-synaptic neurons to post-synaptic neurons results in a transfer of information which causes cellular or molecular changes in these neurons and leads to memory consolidation (Fustar 1995). Specific brain areas involved in memory consolidation include the hippocampus, amygdala and the cerebral cortex itself. In order for these cellular changes to take place the brain must have a constant supply of energy (Kandel *et al.,* 2000).

1.5.2 The Earliest Breakfast and Cognitive Performance Research

The very earliest research on how breakfast might affect performance were mainly on schoolchildren where pupils were provided with supplementary food and then subjectively assessed for behavioural differences . At the time quantitative assessment was not possible. In 1931 Laird *et al.* conducted an experiment on 53 schoolchildren described as 'nervous' by their teachers, as assessed by using a 'behaviour checklist' of 34 nervous traits. They were divided into 3 groups and for 5 mornings a week and at 9.30 am group 1 had no extra food but spent 10 minutes playing, group 2 received half a pint of milk and group 3

received half a pint of milk together with food concentrate. Group one showed a slight decrease in 'nervousness' after 2 weeks. The children in 2 showed an average improvement of 6% and group 3 showed an improvement of more than 13% in terms of nervousness of the average child and all but 15 % of children consuming this breakfast showed a reduction in nervousness. Some of the children came to school having eaten breakfast whilst others had 'only a hasty morsel'. However the children's normal breakfast habits were not analysed in this study.

The 'Oslo breakfast' was compared with milk in 419 boys and 212 girls (5-16 yr) by Bigwood *et al.* (1947). Children on the 'Oslo breakfast' group consumed 210-225 mls of milk together with brown bread, butter, cheese or ham, fruit, sugar and jam, whilst the other group consumed 420-450 mls of milk. The 'Olso breakfast' contained about twice the amount of energy, protein and fat as the milk supplement. Forms were completed by nurses and teachers and the 'general demeanour' was more often improved in the boys given the 'oslo breakfast' and girls given either milk or 'Oslo breakfast' improved to an equal extent.

The effect of 'poor' breakfasts (undefined) and consequent blood sugar level on the behaviour of 350 schoolchildren was investigated by Galloway *et al.* (1948). Signs of lassitude, fatigue, inattention, misbehaviour, complaints of headache, pain in the stomach or nausea, crying or over-emotional behaviour were recorded by teachers for a number of weeks. It was reported that children who ate a 'poor' breakfast were not as attentive or energetic as those eating 'good' breakfasts. Blood glucose levels were within normal limits for all the subjects, including the nine children who came to school without breakfast.

Differences in late morning behaviour of children who had a supplement of pineapple juice was conducted by Keister (1950). Pineapple or water was served daily at 10.00 to 76 boys and 57 girls aged between 27 and 60 months. It was reported by trained observers that for the majority of subjects the supplement relived tiredness, reduced tension and irritability

and in promoting a feeling of well-being. It was noted stated whether the observers were aware of the experimental and control groups.

1.5.3 The Iowa breakfast studies

The Iowa breakfast Studies were a series of studies carried out over 50 years ago and were the first series of studies to suggest that breakfast enhances performance (Tuttle *et al.*, 1949, 1950, 1952, 1954). The main aim of these studies was to evaluate the effects of varying breakfast regimens on physiological performance. Whilst some of the studies also included tests of mental performance, these were limited mainly to reaction times to a task. In the first set of experiments in 1949 Tuttle *et al* compared the effects of four breakfast regimes (1) a heavy breakfast of 800 kcal (2) a light breakfast of 400 kcal (3) no breakfast and (4) a coffee only, 60 kcal. Simple and choice reaction time were tested in six females aged between 22 and 27 years in addition to a range of physiological measures. There was a tendency towards slower reaction times in the no-breakfast condition. The study was repeated with the same set of subjects. Five out of the six and three out of the six showed a significant increase in simple reaction and in choice reaction time respectively in the no-breakfast condition. These findings should obviously be treated with caution since the subject group was so small.

In 1950 Tuttle *et al.* carried out similar experiments in 10 males aged 21 to 28 years, testing subjects 3 hrs after a breakfast of 750 kcal or no-breakfast. The findings were conflicting again with six of the subjects showing no change in reaction time in the no-breakfast as compared to 750 kcal breakfast, 3 showed a significant increased in reaction times, while one subject's reaction times increased significantly during the no-breakfast condition. This study was in conclusive due to the small sample size again. In the 1952 studies Tuttle *et al.* found that there was no effect of different breakfasts on reaction times. Three breakfast were compared (1) bacon, egg and milk breakfast, (2) no breakfast and (3) a cereal and milk breakfast. Over a period of 13 weeks ten men aged 60-83 years were tested to elucidate the effects of these 3 breakfast conditions. For the first 5 weeks subjects

received the bacon, egg and milk breakfast, followed by 4 weeks with no breakfast and 4 weeks on cereal and milk. During the course of the experiment no change in reaction times was found for seven out of the eight subjects. Although the study examined the long-term effects of breakfast the poor experimental design, small sample size and the use of only a few measures of performance decreases the value of the experiments. The last set of experiments carried out by Tuttle *et al.* in 1954 looked at school achievement and the attitudes of schoolboys aged 12–14 years. Assessments were subjective and made by schoolmasters and suggested that consumption of a cereal-and-milk breakfast had a favourable effect on attitude and school performance. Choice reaction time was not altered by missing breakfast. Dickie and Bender 1982 have criticised these early studies for their small group numbers, for the use of subjective assessments and for producing inconsistent findings.

1. 5.4 The Last 40 years of Research

Research from the last 40 years has been divided into 3 types namely studies evaluating (1) the acute effects of breakfast omission on cognitive performance (2) the effects of school breakfast programs on cognitive and behavioural performance (3) the effects of glucose administration on cognitive performance. A summary table of these 3 types of research can be found at the end of each section (tables 1.c, 1.d and 1.e) . There has been a relatively small amount of research on (1) and these studies are heterogeneous in subjects, designs and outcome variables ,and their results are far from conclusive (Lopez *et al.,* 1993). For this reason the 4 main research groups looking into the effects of breakfast mission on children have been described and discussed below and where possible they have been placed in chronological order.

Where there is a positive association between breakfast and cognition the results are in bold. The 3 areas of research have also been summarized below.

1.5.4.1 The acute effects of breakfast omission on cognitive performance

Breakfast omission and tests of short-term memory have been the most widely studied (see table 1.c). Diminished speed and accuracy on tests of visual and auditory short-term memory, immediate recall, delayed recall, recognition memory and spatial memory were observed in children and young adults (Pollitt *et al.,* 1981, Simeon 1989, Vaisman *et al.,* 1996, Benton *et al.,* 1998, Smith *et al.,* 1992 & 1994). Cognitive functions also unrelated to memory were influenced by missing breakfast. Three studies of children reported lower performance in visual discrimination of competing stimuli (Pollit *et al.,* 1998 and Simeon *et al.,* 1998).

A decline in performance in a verbal fluency test (Simeon 1998 and Grantham-McGregor *et al.,* 1998), tasks of arithmetic, continuous visual stimulus (Conners *et al.,* 1983), and stimulus discrimination Pollitt *et al.,* 1981) was associated with the no-breakfast condition. Although the data from these experiments cannot be directly compared because of differences in methodology and the types of tests used the findings suggest that attentional processes that relate to short-term memory are vulnerable to a prolonged fast (see table1.c).

Tests that require sustained attention e.g. a repeated vigilance task were not affected by breakfast omission (Smith *et al.,* 1992 and 1994), nor was speed of general knowledge retrieval (Simeon *et al.,* 1989 and Smith 1992).

There were some studies where none of the cognitive function measures related to memory, computational skills, or attentiveness were significant between the breakfast and the no-breakfast groups (Cromer *et al.,* 1990, Dickie *et al.,* 1982, Lopez *et al.,* 1993 and Lloyd *et al.,* 1996). The reason for finding no differences could be the lack of controlling for confounders. In the Cromer study for example it is possible that the test used to measure cognitive function was not an effective measure for the group being studied; the Matching Familiar Figures Test may have been too easy for the adolescents in the study. The computerized test used in a group of Chilean children (Lopez *et al.,* 1993) from low

socio-economic backgrounds may have been highly motivational since they were using a computer for the first time and this could have lead to the apparent lack of a breakfast effect.

TABLE 1. c Studies evaluating the acute effects of breakfast omission on cognitive performance

Study, location, setting and year	Sample characteristics	Study Design	Results	Comments
Pollitt *et al.* U.S.A, metabolic ward, 1981	32, 9-11-y old middle-class, well-nourished children	Randomized, blinded, crossover study of BR[2] and BR. BR served 0800-0830 Cognitive test (IQ, MFFT, HCIT) given at 11 15. Crossover after 1 week.	**Subjects made more errors in a task of picture indentification (MFFT) with NBR than BR.**	
Pollitt *et al.* U.S.A, metabolic ward, 1983	39, 9-11-y old middle-class, well-nourished children	Randomized, blinded, crossover study of BR[2] and BR. BR served 0800-0830 Cognitive test (IQ, MFFT, HCIT) given at 11 15. Crossover after 1 week.	**Subjects made more errors in a task of picture indentification (MFFT) with NBR than BR**	
Conners & Blouin, U.S.A, metabolic ward, 1983	10, 9-11-y well nourished children	Intervention of BR[3] or NBR on 4 occasions 1 week apart on all subjects. Tests (CPT arithmetic) assessed at 0950, 11 00, and 12 10.	**Subjects performed better on a CPT of visual stimuli (a test of attention span and viligance) and an arithmetic test after BR than after NBR.**	Small sample size.
Simeon & Grantham-McGregor, Jamacia, metabolic ward, 1989	90, 9-11-y old children Group 1: severely malnourished in first 2 y of life (n=30) Group 2: stunted in growth (n=30), Group 3:average growth (n=30).	Randomized, blinded, crossover study BR[4] or NBR group. BR served at 08 00. Cognitive tests – WISC-III (coding, fluency, arithmetic, digit span (backward and forward). MFFT given 11 00. Crossover occurred 1 week.	**With NBR, groups 1 and 2 had lower scores on verbal fluency and coding tests than with BR. Similarly, wasted children had lower scores MFFT** **Test and digit span test NBR. BR omission did not significantly impact performance in adequately nourished children (group 3), with the exception that on one task (arithmetic).**	Low height-for age is an indicator of undernutrition

TABLE 1.c: Studies evaluating the acute effects of breakfast omission on cognitive performance

Study, location, setting and year	Sample Characteristics	Study Design	Results	Comments
Chandler *et al.* Jamaica, school, 1995	197, 8-11 year old children with low SES from rural schools. 97 were undernourished (low weight-for age) and 100 were adequately nourished (normal weight-for-age)	Randomised crossover study of BR[5] and NBR[6]. Tests of verbal fluency, digit span, visual search, and speed of information processing week given. Crossover occurred after 2 wk.	**Undernourished children had a lower performance score on a test of verbal fluency with NBR.**	Timing of BR and administration of cognitive tests not reported.
Pollitt *et al.* Peru, home 1997	52, 9-11-y old lower-middle-class, 23 undernourished, 29 well-nourished	Randomised crossover study of BR[7] and NBR condition. BR served at 0800. Cognitive tests (stimulus discrimination, SMST) given at 1100.Crossover occurred after 1 wk.	**Performance on SMST and SDT were adversely affected during the NBR period among the undernourished children.**	
Vaisman *et al* .Israel, school 1996	491, 11-13 y old boys and girls with varying SES backgrounds	Subjects reported on the types and amount of BR foods they had eaten on the day of experiment. Tests (AVLT and for memory for narrative prose and visual memory) given at 0855-0935 at school.	**On a task of immediate recall, children with BR scored significantly higher than those with NBR.**	No standardization or control of BR eaten at home in relation to composition and timing.
Vaisman *et al,* Israel, school, 1996	503, 11-13-y old boys and girls with varying	Exceptional subjects participated in a 2-wk study. Subjects were told not to eat anything at home. Subjects ate BR[8] at 0800-0820. Test (AVLT and memory for narrative prose and visual memory) were given at 0855-0935 at end of 2 wks.	**All test scores were significantly higher for those who ate BR at school compared with those who ate BR at school compared to those who ate BR at home or those who ate NBR. Researchers suggested timing of BR is important because the subjects who ate 30 min before testing performed better than those who ate at home > 2 h before testing.**	66% of control subjects ate BR at home.There was no standardization of composition timing of BR consumed at home

Table 1.c con'td

Study, location, setting and year	Sample Characteristics	Study Design	Results	Comments
Benton and Parker U.K, research laboratory 1992	33 university students, average age =21yr	Subjects fasted from the time of their evening meal the previous day and had NBR or a milk-based nutritional beverage. Tests (spatial memory, immediate recall) were given 2 h after BR.	**The BR group took less time to finish memory tasks than the NBR group.** The number of errors was not influenced by BR consumption.	
Smith, U.K, research lab, 1994	48 university men and women	Subjects assigned to NBR, cooked BR[9], or cereal-and-toast BR[10] with coffee or decaffeinated coffee. Subjects were fasted from 0000 and were tested 0800-0830. Additional tasks (reaction time tasks, serial response tasks and RDVT) were given at 0930 and 1030.	BR had no effect on performance of sustained attention tasks, although it increased pulse rate and influenced mood. Caffeine improved performance of sustained attention tasks and increased mental alertness. **Improvement in mood was also observed with a cooked BR.**	
Smith, U.K, research lab, 1992	48 university men and women	Similar design to Smith , 1994, using different tests (free recall, delayed recognition, memory task, semantic processing task, RDVT). Only the NBR and the cooked BR conditions were used.	**BR improved the subjects' performance on free recall and recognition tasks**, had no effect on a semantic memory task. BR had no effect on the RDVT performance (which is a measure of sustained attention). **BR had an effect on free recall in mid-morning but no effect in late morning.**	
Lloyd *et al.* 1996	18 adult habitual breakfast eaters	On the same day on 4 consecutive weeks, subjects ate	**A significant improvement in mood was observed in the low fat, high-CHO BR group.**	

		NBR; low-fat, high-CHO BR[11]; medium-fat, medium-CHO BR; or high-fat, low-CHO BR. BR served at 0830. BVIP (memory), 2-finger tapping task (motor speed), free recall, and reaction time tests were given at 30, 90 and 150 mins after BR.		

AVLT Rey Auditory-Verbal Scale, BVIP, Bakan Visual Information Processing Test, CPT, Continuous Performance Task, HCIT, Hagen Central Incidental Test, IQ Intelligent Quotient, MAST, Memory and Search Test, MFFT Matching Familiar Figures Test, RDVT, Repeated Vigilance Task, SDT, Stimulus Discrimination Test, SES socioeconomic status, SMST, Sternberg Memory Search Test, STAIC, State-Trait Anxiety Scale

BR, breakfast or subjects who ate breakfast, NBR, no-breakfast or subjects who ate no breakfast

[2]Waffles, syrup, margarine, orange juice and milk
[3]Cereal with sugar, milk, eggs, juice and toast.
[4]Cheese, nutribun and milk
[5]Cheese sandwich and chocolate milk
[6]Orange slice
[7]Grain cake, milk substitute
[8]Sugared Corn Flakes and whole milk
[9]Srambled eggs with semi-skimmed milk, bacon, whole-meal bread, and margarine
[10]Cornflakes, semi-skimmed milk, sugar, whole-meal bread, margarine and marmalade
[11]Each breakfast consisted of bread rolls, margarine, jam and a milk shake. Fat content was manipulated by varying the margarines and adding cream to milk shakes. Carbohydrate content was increased by adding maltodextrin.

1.5.4.2 Studies evaluating the effects of school breakfast programs on cognitive and behavioural performance.

School breakfast feeding programmes have until recently been confined to the U.S where school breakfast has been served since 1966 and developing countries such as Jamaica, India and Peru. In 1999 the white paper highlighted the need to improve the diets of school children in the United Kingdom (DoH, 1999). The proposal to provide some of Britain's poorest children with a breakfast at school was passed and breakfast clubs were opened up in deprived areas of the U.K. There are now over 5000 breakfast clubs operating in the U.K.

The results of the research into school breakfast programs (SBP) in the U.S and developing countries have been described below and are summarized in table 1.d. Research into breakfast clubs in the U.K have also been described and summarised below.

The US Department of Agriculture School Breakfast Program (USBP)

The School Breakfast Program (SBP), authorised by the Child Nutrition Act of 1966, started as a pilot program to provide funding for school breakfasts in poor areas where children had to travel a great distance to school. In response to the body of evidence suggesting educational and dietary benefits, many observers urged that the availability of school breakfasts be expanded. The United States Department of Agriculture (USDA) now oversees the largest school breakfast program in the world. SBP participation grew rapidly from 1970 to 1980, but more modestly through the 1980s (Kennedy 1998). Participation has grown dramatically over the past decade. The number of schools offering SBP increased from 46 100 in 1991 to 68 718 in 1997 now serving approximately 7 million children (Briefel *et al.,* 1999). SBP breakfasts are required to provide approximately one-fourth of the Recommended Dietary Allowance (RDA) for important nutrients over a period of time (protein, Ca, Fe, vit A, vit C, and calories). The school breakfast must contain the following food components:

- A serving of fluid (whole or low-fat) milk served as a beverage or on cereal or used in part for each purpose
- A serving of fruit or vegetable or both, or undiluted fruit or vegetable juice
- 2 servings from one of the following components—bread/bread alternative or meat/meat alternative; alternatively, there can be one serving from each component.

Optimum nutrition for optimum cognition was a conceptual foundation (Pollitt *et al.*, 1984). Despite the historical impression that breakfast improves cognitive performance, data from the earlier studies were inconclusive and positive findings were questionable because of poorly controlled study design.

In the last 20 years, several well designed investigations have looked at USSBP and it's effect on cognitive function have shown positive results . Meyers *et al.*, 1989 carried out a longitudinal study which looked at SBP participants versus NSBP (non school breakfast participants). Participants carried out the Comprehensive Tests of Basic Skills (CTBS) battery which has language, reading and mathematics subtests. Participation in the SBP increased the CTBS total scale and decreased lateness and absenteeism. Worobey *et al.*, 1999 looked at the nutritional differences between NSBP and SBP in pre-school children. The results showed that when breakfast was altered to provide the nutritional profile of a SBP breakfast performance was improved. Unlike previous breakfast studies which did not show a pronounced effect when using computer tests of vigilance (Conners and Blouin 1983, Pollitt *et al.*, 1981) was seen in the SBP group.

Whilst differences between SBP and NSBP were found for younger children Cromer *et al.*, (1990) were unable to find differences on a battery of psychological measures that assessed short-term auditory memory, vigilance, impulsivity and mood in adolescent children. The adolescents were supplied with a SBP versus a control group who received a very low calorie meal. Serum glucose and B-hydroxybutyrate (reflecting the breakdown of

an alternative fuel to compensate for reduced hepatic glycogen) were also measured and did not correlate with any behavioural measure. The authors conclude that whilst these findings suggest no effect of the school breakfast that the middle-class adolescents may not be a vulnerable enough group to show nutritionally based cognitive deficits.

School Breakfast Programmes in Developing Countries

Jamaica

School feeding programs have operated in Jamaica for decades and in 1973 the government implemented a structured program that was expected to benefit both school achievement and attendance. 2 studies were designed to evaluate this one of which looked at the difference between children who ate breakfast and those who fasted (Simeon *et al.*, 1989). Verbal fluency, sustained attention and short-term memory were worsened by the NBR condition in severely malnourished and stunted children .

Their first study however looked at the effects of the Jamaican school meal versus a control meal on achievement, attendance, and physical growth. Undernourished were divided into 3 groups those who were given the school breakfast (banana cake or meat and vegetable pastry with milk), those who ate no breakfast and a control group who were given syrup. School breakfast had a significant effect on arithmetic scores and attendance.

Studies in Peru

Pollitt and colleagues looked at the effect of BR versus the NBR condition in undernourished and well-nourished children (Pollitt *et al.*, 1997) as summarised in table1.D. They found that whilst performance on a memory and discrimination test was affected by the NBR condition in undernourished there was no effect on the well nourished population. The study prior to this looked at SBP and NSBP participants and found that

children who were nutritionally at risk improved their vocabulary tests score after SBP participation. Also school attendance was increased by SBP participants.

It is evident that much of the research into school breakfast programs have therefore looked at facets other than cognitive function. Many are concerned with how school breakfast will effect behaviour, attendance and how overall this will effect school achievement. In fact many outcomes have been improved by school feeding. These outcomes can be divided into social and biological mechanisms. The provision of subsidised or free meals would reduce the parent's costs of sending children to school and may improve both the childrens' and parents' attitude towards school. Improved attitudes might lead to better attendance. Children may arrive earlier in the morning and thus be on time for the first lesson. Consistent and regular attendance ensures that the sequence of instruction is maintained and should facilitate learning.

Hungry children may be too sleepy or easily distracted to pay attention to learning tasks. It has been shown that the more time children spend on a task the more likely they are to learn (Carroll, 1963). Therefore school breakfast may not only increase the time physically spent in school but may increase the time spent on educational tasks.

When children miss breakfast at home they may suffer short term hunger during morning school work. This may result in impaired memory and attention spans and the reduced efficiency of information processing. These effects can be relieved by providing school breakfast and this can enable children to learn more in the time available.

It is also possible that school breakfast can improve intellectual outcomes by correcting any specific micronutrient needs of the children which may lead to low achievement. For example a school breakfast may correct for iron deficiency anaemia and thereby improve the achievement of iron deficient children (Pollitt, 1990). It is likely that school breakfast in the long term will result in overall improvements in general nutritional status which

could affect cognition. The hypothesized relations among these outcome variables are shown below in figure 1.b.

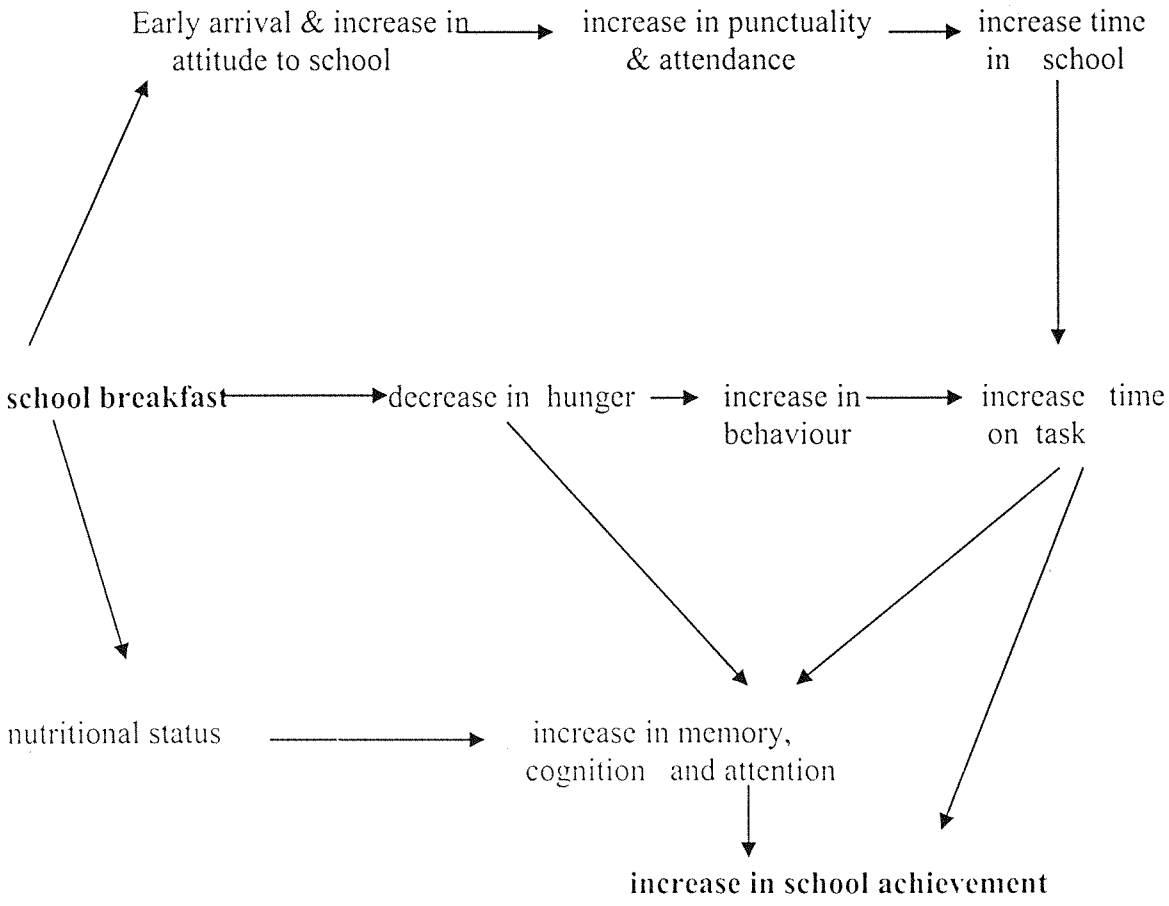


Figure 1.b: The Effects of Breakfast On Educational Performance, Attendance and Classroom Behaviour

This diagram also illustrates some of the hypothesize explored the current research.

Research into Breakfast Clubs in the U.K

The New Policy Institute (NPI) Research

Until recently research into breakfast clubs in the U.K have remained relatively small scale. The New Policy Institute (NPI) together with the Kid's Club Network have carried out an evaluation of 58 breakfast clubs who won awards in the 2000 UK-wide Breakfast Clubs Award Scheme (Harrop and Palmer, 2002). The study comprised two surveys of the

winning clubs, undertaken at the start end of the 2000/01 school year respectively, plus more in-depth case studies during the year in 10 selected clubs. The aims of the research looked at the effect on the breakfast clubs on :

(1) health and nutrition

(2) improving children's education

(3) children's social needs

(4) parent and family life

Under improving education the survey looked at attendance at school, punctuality, concentration and academic performance during the morning. Questionnaires were given to the schools, children and parents in order to determine how each of these areas were affected. The schools' perspective on how education was affected by the breakfast clubs is outlined :

Evidence from the survey of all clubs: clubs educational benefits (29 responses)

Attendance at school: three quarters felt that the club had helped to improve attendance at the school. One in five said that the club had contributed to significant improvements.

Punctuality: three quarters also felt that the club had helped improve punctuality. A quarter thought that the club had contributed to significant improvements.

Concentration during the morning: four in five schools felt that the club had helped improve concentration in morning lessons, although few reported significant improvements.

Academic performance during the morning lesson: half felt that the club had helped improve academic performance in morning lessons. However , few reported significant improvements and one third said they were unable to give an opinion.

Only a minority of children attended the breakfast club on a regular basis. Therefore the improvement in these children would not be expected to have an impact on the school's overall performance, particularly over a single year. However the investigators undertook

an analysis of academic results in 2001 compared to 2000. There was no significant improvement in grades over the school year.

Whilst this study is an important insight into how breakfast clubs might influence school learning the mainly qualitative analysis used does not give us an in-depth or comparable view of how breakfast may affect cognition.

The National Evaluation of School Breakfast Clubs

The national evaluation of breakfast clubs was researched by the University of East Anglia and Norwich and the Department of Health. (NEA, 2002) A cluster randomized controlled trial was carried out which looked at the effectiveness of breakfast clubs in terms of nutritional, social, psychological and educational outcomes. The results of this work remains unpublished and there are as yet no set dates for publication (Acapella, personal communication).

TABLE 1. d Summary of key studies evaluating the effects of school breakfast on cognitive and behavioural performances

Study, location, setting and year	Sample characteristics	Study Design	Results	Comments
Powell *et al*, Jamaica, , 1983	Undernourished children, average age 12.5 yrs, wit the lowest standard achievement scores. 44 were given BR, 38 were given NBR, 33 cntrol subjects were given syrup.	Longitudinal study with 2 controls. school progress monitored for 2-3 month before and after SBP[2] intervention. Growth and achievement score were assessed, with the WRAT.	**School breakfast had a significant effect on arithmetic scores and attendance .**	
Meyers *et al*, U.S, 1989	Low-income public schoolchildren in grades 3-6 were classified as a SBP participant (n=335) or nonparticipant (n=688).	Longitudinal study with SBP[3] participants and nonparticipants. School achievement scores were assessed by the CTBS before the SBO was in place and 3 months fatter.	**Children who attended the SBP increased the CTBS total scale score and decreased tardiness and absenteeism.**	Subjects were Classified as SBP participants if they attuned the SBP 60% of the time, and non-SBP if they did not attend SBP on any of the days monitored.
Jacoby *et al*, Peru 1996	Children from low SES rural schools. 201 in SBP group and 151 non-SBP.	Short term study evaluating the Scholastic performance of SBP[4]. Cognitive tests were given 15-30d after implementation.	**Only children in the nutritionally at-risk group improved in their vocabulary test scores after SBP participation**	
Wyon *et al*, 1997	195 families in well nourished population	provided with standard breakfasts with either low or high energy content. children were randomly assigned to breakfast alternative on any given day	**Voluntary physical endurance and the performance of a creativity test were significantly better after a breakfast from which children derived over 20% of their recommended daily energy intake than after a breakfast from which they obtained less than 10% of recommended values.**	
Worobey and Worobey 1999	4 yr old children at pre-school	Baseline breakfasts at home, SBP BR and measurements after 6 weeks	**SBP breakfasts improved performance on matching figures test.**	

BR, breakfast or subjects who ate breakfast; CTBS Comprehensive Test of Basic Skills; NBR, no breakfast, or subjects who ate no breakfast; SBP, school breakfast program; SES, socio-economic status; WRAT, Wide Range Achievement Test

[2]Banana cake or meat and vegetable pastry with milk

[3]Type of breakfast served was not specifies

1.5.6 Breakfast studies evaluating the effects of glucose administration on cognitive performance

As indicated in table 1.e there have been a number of experiments which have shown that glucose pays a role in cognitive function. Benton and Parker , Korol and Gold have all shown that tasks requiring recall from memory are improved after administration of glucose (see table 1.e, page 74). The mechanisms by which glucose can affect cognition have been discussed below.

1.6 Mechanisms by Which Food Can Effect the Brain

Food provides the energy needed for internal organs and affects metabolic pathways. The brain regulates food intake through complex processes related to thermogenesis, appetite control, and feedback mechanisms that indicate a state of hunger or satiety. The absorption of food causes further signals to the brain via physical, biochemical, osmotic, and hormonal responses (Anderson, 1996). The specific content of the food affects certain biochemical and hormonal functions in the body and brain, thus linking diet to behaviour and cognition. In fact rapid and specific changes in brain composition normally occur after each meal (Wurtman *et al.,* 1974).

The acute affects of meals on mental performance and the potential of particular foods to influence various aspects of the psychological state, mental and physical performance and well-being is a rapidly growing interest. The mechanisms through which the macronutrients (CHO, protein and fat) can influence the neurochemistry or neural functioning of the brain are beginning to be understood (Dye *et al.,* 2000). Whilst micronutrients (vitamins and minerals) have been shown to both impair and improve some aspects of cognitive performance the effects of these nutrients is implicated over a longer term (i.e. acute effects are unlikely) and is more likely to effect at risk populations, e.g. the elderly and the malnourished. The mechanisms by which the macronutrients can acutely

effect cognitive performance is discussed below with particular interest to the effect of carbohydrates. The effect of micronutrients is also described at the end of the section.

1.6.1 Carbohydrates and Mental Performance

Unlike other organs, the brain's energy requirements are met almost exclusively through aerobic glucose degradation (except during times of no carbohydrate intake and ketosis). Although weighing only 2% of total body weight, the brain uses approximately 20% of the body's energy at rest (Benton *et al.,* 1998). The brain's energy stores are relatively small and without a constant supply of glucose these stores would be depleted of glucose in less than 10 minutes. Blood glucose levels rise after eating, especially if the meal is carbohydrate rich. This is counteracted however by the release of insulin that promotes the storage of unneeded glucose to glycogen in the liver (and some to muscles and adipose issue) (Fray, 1996). It was traditionally assumed that through this homeostatic mechanism the brain is well supplied with glucose it's primary fuel and that its functions is not affected by normal fluctuations and variations in blood glucose (Booth, 1994). Recent evidence suggests however that raising blood glucose concentrations improves cognitive functioning (Hall *et al.,* 1989, Benton and Owens 1993, Owens *et al.,* 1994, Gold *et al.,* 1986, Messier 1987, Green *et al.,* 1997). The scientific evidence to support this belief is still debated but there are several hypothesise.

1.6.1.1 Mechanisms to Support the Role of Glucose and Cognition

Role of Neurotransmitters and glucose

Glucose is the primary source of energy for the brain and is essential for the normal functioning of the central nervous system (Sieber and Traystman 1992). The fact that glucose is able to cross the blood-brain barrier by the process of active transport is an important clue in understanding how it might effect cognition. Exactly how glucose effect mental performance remains debated. The fact that glucose crosses the blood-brain barrier by active transport (Wenk 1989) and that it is used in a huge number of biochemical processes is of key importance. Glucose levels influence the activity level of, and are

influenced by other neurotransmitters, including dopamine, seretonin, norepinephrine and it is a key substrate for acetylcholine (Benton *et al.,* 1994, Messier and White 1987, Wenk 1989, Ragazzino, Gold 1994).

Glucose Enhancement of Memory is an Inverted-U Dose-Response Curve

The memory enhancing effects of glucose and ephinephrine have an inverted-U dose-response function (Gold 1986; Hall and Gold 1986); also injections of ephinephrine and glucose in rats at doses optimal for enhancing memory result in comparable blood glucose concentrations (Hall *et al.,* 1986 and Hall *et al.*, 1992). The evidence for this inverted-U dose-response comes from work in animal studies (Gold 1986) and elderly humans (Parsons and Gold 1991). Low doses are without effect, intermediate doses enhance memory, and higher doses either have no effect or impair memory. Optimal glucose enhancement of memory storage in rats is seen at doses (e.g., 100mg/kg) which results in elevations in blood glucose levels from 120 to 160 mg/L (Hall and Gold 1986).

Gold and colleagues) carried out a series of experiments looking at this effect in elderly humans. In 3 experiments he was able to demonstrate that glucose administration enhances performance in a logical memory test (Hall *et al.,* 1989, Manning *et al.,* 1990 and Parsons *et al.,* 1991). In thc last of these experiments the researchers were able to show that the blood glucose levels which are optimal for memory storage in humans is from ingestion of 25g of glucose which equates to blood glucose levels of approximately 150-175 md/dL. This is the same level in rodents and this adds evidence to support the view that the underlying mechanisms behind which glucose enhances memory in humans and animals share important commonalities. The storage and or utilisation which is of glucose appears to be of importance for cognitive performance.

The Role of Glucose in the Mechanism of action of Cognitive Enhancers

The pioneering and innovative studies of the "glucose enhancement of memory enhancement" investigated by Gold and colleagues, has provided the conceptual

framework for the hypothesis for the role of glucose in the mechanism of action of cognitive enhancers.

Many drugs have been tested for their ability to enhance the cognitive performances that underlie learning and memory. Drugs which provide precursors for the formation of acetylchloine e.g. choline, lecithin or phosphatidylseine treatment, or slow the degradation of synaptic acetylcholine e.g physostigmine or tetrahydroaminoacridine have been shown to increase performance (Bartus *et al* 1982). Many of these drugs have been tested in patients with Alzheimer's disease (Mohs *et al.* 1985 and Summers *et al* 1986), a disorder characterized by significant cholinergic cell loss (Davies and Maloney 1976).

It has been proposed that some cognition enhancing drugs produce their beneficial effects on learning and memory by increasing the availability of glucose for uptake and utilization into the brain. The hypothesis further suggests that many cognition enhancing drugs act through a peripheral mechanism rather than directly on the brain which is illustrated in the diagram below.

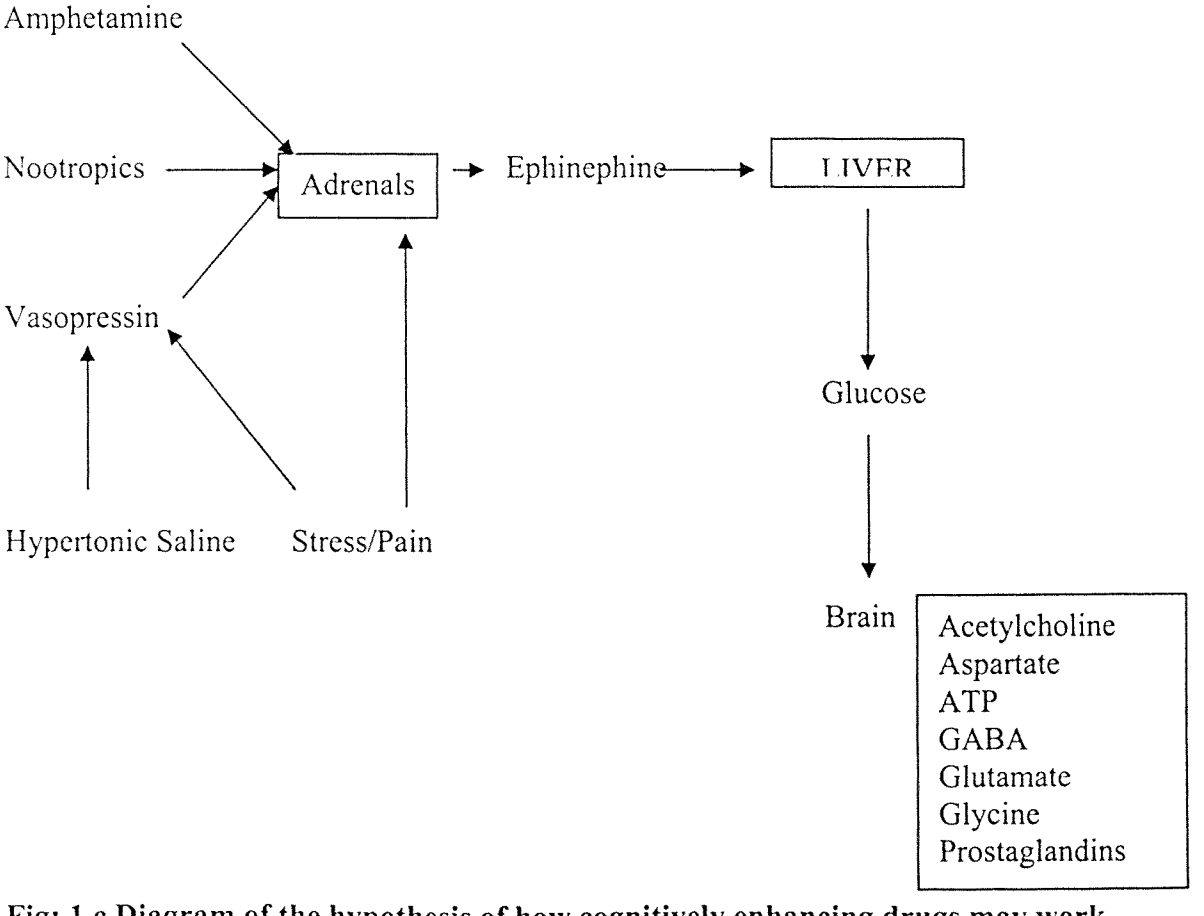


Fig: 1.c Diagram of the hypothesis of how cognitively enhancing drugs may work

TABLE 1. e Summary of key studies evaluating the effects of glucose administration on cognitive performance

Study, location, setting and year	Sample characteristics	Study Design	Results	Comments
Benton and Parker , 1998	80 university women	Subjects followed their usual routine of eating or skipping BR. Subjects were randomly assigned to 1)BR with drink of 50g glucose 2)BR with placebo drink 3)NBR with drink containing 50 glucose and 4)NBR with placebo drink. Testing began 20mins after drinks.	Groups 1,2 and 3 had similar performance n the Brown Peterson task (recall of trigrams while counting backwards). **Group 4 did not perform as well as the other 3 groups.**	BR consisted of cereal and milk, cereal and toast, or all.
Benton and Parker, 1998	137 women, 47 men	As above	Among the NBR subjects, group 3 recalled more words on a word recall task than group 4. **A task requiring recall of a story was improved only by BR and not by a glucose drink.**	
Hall *et al,* 1989	College-age and elderly subjects	On 2 occasions 1 week apart, subjects were tested in the morning after an overnight fast. Subjects consumed lemonade sweetened with 50g glucose or a placebo drink with 50g glucose or a placebo drink with saccharin.	**Improved performance on a test of contextual verbal memory of a prose passage after glucose administration was observed with the elderly only.**	
Craft *et al*, 1994	27 young adult and 32 subjects	Design as Hall et al. Task of complex memory and non memory were given.	**Glucose improved performance on declarative memory.**	
Korol and Gold, 1998	18 college students	Design at Hall and tests relevant to age group	**Glucose improved performance on a test of immediate and delayed recall of prose, attention and completion of a vigilance test**	
Benton *et al*, 203	50 female university students	Subjects were randomly assigned to 4 breakfast condition 1)NBR, 2)low glycaemic index breakfast (GI) and 3) high GI breakfast and 4) glucose drink.	**The influence of the GI of the breakfast on verbal memory was measured in parallel to the assessment of blood glucose levels. A low GI rather than a high GI diet improved memory in humans, especially in the late morning.**	

BR, breakfast or subjects who ate breakfast; NBR no breakfast condition, BG blood glucose.

1.6.1.2 Glucose and Mental Performance in Young Healthy Populations

Evidence from positron emission tomography suggests that increased neural activity (e.g, the learning of a complex visuospatial motor task and verbal working memory) is associated with increased use of glucose by the brain (Haier *et al.,* 1992a, Jonides *et al* 1997). After learning a task, use of glucose in extraneous brain areas decreases (Haier *et al.,* 1992b). Cognitive demand, therefore, seems to be associated increased glucose metabolism localised areas of the brain (Benton *et al.,* 1996 and Kennedy *et al.*, 2000) and consistent with the notion that cognitively demanding situations can deplete the brain of glucose.

It follows that subjects with higher levels of blood glucose and good glucose tolerance (i.e., the ability to transport glucose from the bloodstream to the brain) should respond most efficiently to the demand of cognitive tasks. The threshold for the impairment of cognitive tasks has shown to be in the range of 2.2 to 2.8mmol/L (Widom *et al.,* 1990). Some individual however have maintained normal performance at below 2.2 mmol/L, and others showed disruption of function at 4 mmol/L. As outlined above it has been suggested that cognitive disruption at higher glucose levels occurs in non-diabetics whose symptoms of hypoglycemia are relieved by food intake (Snorgaard *et al.,* 1991).

In both young and aged rodents, glucose administration has been associated with enhanced memory (Gold 1986, 1991, 1992). As discussed, a similar phenomenon has been found in elderly humans (Gonder-Frederick *et al.*, 1987; Hall *et al.,* 1989) and Alzheimer patients (Manning *et al.,* 1993). This research has also extended to healthy young adults. For example, Benton and colleagues have carried out a number of studies which has produced a wealth of evidence documenting the beneficial effects of a glucose drink on cognitive performance in healthy young adults (see table 1.e).

In the first of these experiments Benton and his research group looked at the effect of a glucose drink on 6 and 7 year old children who were given a drink that contained either

25g of glucose or a placebo towards the end of the school day (Benton *et al.*, 1987). They were then subjected to one test that required sustained attention and a second that was intentionally frustrating. Those given the drink containing glucose were more capable of sustaining attention and showed fewer signs of frustration. This finding was reminiscent of the study of Connors *et al.*, (1984), who found that administration of sucrose and fructose to children speeded reaction times and decreased errors on a continuous performance task.

In 1989 Benton tentatively proposed that increasing blood glucose levels improves performance on tasks that demand relatively little mental capacity (Benton *et al.*, 1989). His experiments that followed in 1990 explored this further (Benton *et al.*, 1990) and he was able to conclude that less demanding cognitive task were infact affected by increasing blood glucose.

He re-examined this theory by carrying out 3 studies exploring the role of blood glucose in breakfast-induced improvement of different forms of memory function (Benton & Sargent 1992). In the first experiment they related blood glucose concentrations of 33 university students to performance on 2 tests of memory between those who either did or did not eat breakfast. In the second experiment 80 university students were grouped into 4 groups i.e. 1) ate breakfast and consumed a drink containing 50g glucose 2) ate breakfast and consumed a placebo drink 3) fasted and consumed a drink containing glucose or 4) fasted and consumed a placebo. In the third experiment 194 university students were split into the 4 groups described above. Breakfast consumption improved performance on 3 memory tests. Performance on a spatial memory test correlated significantly with blood glucose concentrations; even relatively small diet-induced differences in blood glucose affected memory function. Breakfast consumption enhanced word list recall and Weschsler story retention confirmed previous reports that eating breakfast was associated with improved memory later in the morning (Dickie *et al.*, 1982, Cromer *et al.*, 1990, Benton *et al.*, 1992, Smith *et al.*, 1992 and 1994). The findings from these experiments and the previous studies listed above indicated that eating breakfast affects tasks that require the

retention of new information. Breakfast did not influence performance in an intelligence test but confirmed previous findings in memory tasks. Declarative memory refers to information that can be consciously recalled and declared verbally whereas procedural memory includes conditioning, habituation, and skills such as riding a bicycle. The enhancement of declarative memory by consumption of a glucose drink in the elderly has already been described previously (Craft *et al.*,1992, Craft *et al.*, 1993, Hall *et al.*, 1989 and Manning *et al.*, 1990).

The 3 experiments carried out by Benton and colleagues confirmed the findings that breakfast enhances recall of stories and word lists. Craft was also able to show this in young adults (Craft *et al.*, 1994). In experiment 1 blood glucose correlated with memory even for those who had not eaten breakfast. In experiment 3, the provision of a source of blood glucose nullified the negative effects of skipping breakfast in some but not all cases.

A further 3 experiments conducted by Benton (Benton *et al.*, 1993a, 1993b and 1995) confirmed that a glucose-enhanced drink can improve memory in healthy young adults. In the first of these experiments an association was found between blood glucose levels and the speed of performance on two attentional tasks. There was a positive correlation in both glucose and placebo drinkers between the baseline blood glucose levels and less forgetting. Those with an initially higher blood glucose remembered more and had faster reaction times the Rapid Information Processing Test (RIPT). They proposed that as an equilibrium develops between plasma and brain glucose (Lund-Anderson 1979) those with initially high levels of blood glucose will have higher levels of brain glucose, a finding consistent with suggestion that high brain glucose levels are associated with better memory. In those receiving a glucose drink high blood glucose levels at the end of the experiment, and a tendency for blood glucose to remain higher while performing the task were both associated with better memory. Whilst it is not possible to measure local changes in brain glucose in humans evidence from tomography suggests that intense cognitive demands leads to local neuroglycopenia.

Others have suggested that the ability to deal with a glucose load influences cognitive functioning. Following a glucose load, blood glucose levels rise, peak, then fall back to baseline levels over the subsequent hour or so (Scholey *et al.,* 2001). A number of studies have identified a clear association between the rate at which glucose levels fall and a better cognitive performance. There are several reports that an inability to deal with a glucose load is associated with a decline in cognitive functioning in animals (Stone *et al.* 1993) and humans (Craft *et al.,* 1992, Gonder-Frederick *et al.,* 1987, Hall *et al.,* 1989). Craft et al (1992) found in the normal elderly that memory was better following a glucose drink only in those who glucose levels fell after an initial rise. In Benton's study falling blood glucose following the baseline RIPT was associated with better memory in those drinking both glucose and placebo, and memory was better if glucose was taken from the blood stream. These findings are similar to those of Craft *et al* but for the first time demonstrated the same phenomenon in young healthy adults.

In the second experiment carried out in 1993 by Benton and colleagues which was a double blind study looking at the effect of a drink containing 50g of glucose, or a placebo, on the ability to recall a word list. They found that those whose blood glucose levels were increasing remembered significantly more words than those whose blood glucose levels were falling. In the 1995 study which examined the relationship between performance on a dichotic listening task and blood glucose levels low baseline and falling levels of blood glucose were associated with more focused attention. High baseline glucose was associated with increased incidental memory and better final recognition. Depending on the demands of the situation, high, low, rising and falling blood glucose levels have all been associated with better memory.

Memory was not the only aspect of cognitive functioning that was shown to be affected by glucose by this group of researchers. Donohoe and Benton (1999) were also able to show that performance on non memory tasks, the porteus maze and a verbal fluency task was better with the consumption of a glucose drink. Performance was poorer in subjects who's

blood glucose levels stayed higher however suggesting that the individual differences in blood glucose control can affect cognitive function, i.e. those who are less efficient at removing glucose from the blood are less competent on cognitive task performance. They suggested that an equilibrium develops between plasma and brain glucose so that those with a higher blood glucose would also have a higher brain glucose.

Foster *et al.* (1998) also found a positive relationship between glucose and cognitive function in young healthy populations. They fasted young healthy female participants overnight and gave them 25g of oral glucose and measured their memory performance on a series of tasks. They found a significant glucose effect on the verbal recall and free recall tasks.

Scholey *et al.* (2001) investigated the theory that there is a reciprocal relationship between falling glucose levels and cognitive performance, particularly under conditions of cognitive demand in a healthy young population. This was a placebo-controlled, double blind, balanced, crossover study which examined the possibility that a high cognitive load may produce changes in blood glucose levels and also looked at the effects of glucose on tasks of varying cognitive demand. They suggested that the amount of cognitive load associated with task performance is an index of its sensitivity to enhancement by glucose. They were also in agreement that a period of intense cognitive processing leads to a measurable decrease in levels of peripherally measured blood glucose, which may be linked to increased neural activity.

1.6.1.3 Studies Showing No Correlation Between Glucose and Cognition

Cormier *et al.* (1993) reported no glucose enhancement of memory in young, or elderly subjects. Azari and colleagues (1993) also reported that even though ingestion of glucose elevated plasma glucose levels there was no memory enhancement effect for glucose in young, health normal adults. Although the findings are in contrast to the reports that

glucose enhances memory in both adult animals (Gold 1986 and Gold *et al.* 1986) and humans (Gonder-Frederick *et al.* 1987; Hall *et al.* 1989) the explanation behind this is unclear.

Whilst some experiments have shown no improvement of performance with a glucose, there is wealth of evidence to suggest that increases in blood glucose concentration from the consumption of a glucose drink has been found to improve performance in healthy young adults, elderly adults and animals. The evidence for more vulnerable groups such as the elderly adults, those with metabolic or cognitive pathologies is stronger. There has been little work carried out specifically looking at glucose administration and children since many cognition studies have looked at the effect of breakfast as a meal and have been non-invasive by not measuring blood glucose levels.

On waking hepatic glycogenolysis is the major buffer against short-term (12-18 hrs) fasting, and since the brain accounts for more than 50% of body oxygen consumption in children (Sokoloff 1976), it would be feasible to say that age, size of the last meal and the ratio of hepatic to brain weight would influence an individual's response to a short fast (Pollitt *et al.*, 1983). The higher ratio of brain weight to liver weight in the child (1.4 to 1.6 versus 0.73 for the adult) and the 50% greater metabolic rate per unit brain weight in the child, places a greater demand on the child's glycogenic stores during a short fast as compared to the adult. The child's relatively small muscle mass in turn limits the availability of glucogenic amino acids for hepatic gluconeogenesis. The earlier ketosis of the briefly fasted child as compared to the adult, as well as greater decline in plasma glucose (Chaussain *et al.*, 1974 and Chaussain 1973) reflect both of these characteristics of glucose metabolism in the child. Taking all these facts into consideration it would seem reasonable to propose that this group are also vulnerable and that breakfast consumption or a glucose drink might benefit performance in this group.

Carbohydrate foods are digested and metabolised to produce glucose. Dietary carbohydrates have different effects on the amount and rapidity of glucose production.

Glucose and fructose (monosaccharides) and sucrose and maltose (disaccharides) are rapidly absorbed from the small intestine. Monosaccharides and disaccharides produce a rapid glycemic response and provide a ready source of energy. Maltodextrins (oligosaccharides) and starch (polysaccharides) have different rates of digestion and glycaemic responses. The rate of breakdown of carbohydrates to glucose may have an effect on cognitive performance therefore depending on the task.

1.6.1.4 Protein and Cognitive Performance

Foods with different proportions of protein and carbohydrate can influence mood and performance by changes in serotoninergic function. The precursor amino acids for monoamine neurotransmitters, strongly implicated in affective disorders, can depend on CHO: protein ratios in the diet (Wurtman *et al.,* 1981).

Synthesis of serotonin (5-HT) depends on the dietary availability of the essential amino acid precursor tryptophan (TRP) (Fernstorm, 1983). An important complication is that TRP competes with several amino acids, the large neutral primarily branched-chain amino acids (LNAA), from the same transport system from blood to brain. If the protein content of the meal is sufficiently low, such as 5% (or less) total energy as protein, then relatively few amino acids will be absorbed from the food in the gut. At the same time, insulin will stimulate tissue uptake of competing amino acids from the circulation, and the plasma ratio of those amino acids (TRP:LNAA) will rise, favouring more TRP entry to the brain (Fernstorm 1983; Yokogoshi and Wurtman 1986). Conversely, a high-protein meal, which would be less insulinogenic, results in absorption of large amounts of competing amino acids into the blood. On the other hand TRP is scarce in most protein sources, and is readily metabolised on passage through the liver; thus, the plasma ratio of TRP to competing amino acids falls after a protein rich meal (Schweiger *et al.,* 1986).

The hypothesis that CHO can reduce arousal is based on the theory that ingesting pure CHO can affect serotonin levels in the brain (Fernstorm and Wurtman 1971, Wurtman *et al.,* 1981). A number of researchers have shown that a food or drink containing a high

proportion of simple CHO, such as sugars or simple starches which are readily metabolised to glucose will lead to a drowsy, unaroused state (Spring *et al.*,1983, Lieberman *et al.*, 1986, Thayer, 1987, Pivonka and Grunewald, 1990). However some studies have not found this effect (Brody and Wolitsky 1983, Reid and Hammersley, 1994, 1995, 1998, Wells *et al.*, 1995) and yet others have found increases in rated arousal (Fredricks, 1969, Duffy, 1975).Whether mood affects behaviour and therefore performance remains debated i.e. whether feeling tired or less aroused 'causes' reduced activity, or whether reduced activity 'causes' the changes in mood. Another conceptual problem is the 'inverted-U' problem between arousal and performance. Foods that reduce arousal may impair performance if arousal was previously medium to low, but improve it if arousal was high.

A number of studies have shown that because CHO causes drowsiness, a high–CHO meal can also impair performance. Spring *et al.* (1983) looked at performance on sustained selective attention 2hrs after subjects ate CHO or protein meals. Older people showed a reduction in performance after the CHO meal.

In a study comparing the effects of complex-CHO and protein lunches on performance in young men, Lieberman *et al.*, (1986) administered an extensive battery of performance tests from 1-5hr after test meals. A simple reaction test revealed significantly slower reaction times after the CHO lunch than after the protein lunch. The Digit-Symbol Substitution Test, a measure of motor copying and concentration, revealed significantly worse performance after the CHO meal, compared with the protein meal. The results of these studies suggest the adverse effects of unbalanced CHO meals on performance involving sustained attention and speed. These findings were consistent results concerning children's performance after a high-CHO breakfast (Conners *et al.*, 1986).

1.6.1.5 Fat and Cognitive Performance

Little decisive research has been carried out regarding the effect of diet fat on performance (Bellisle *et al.*, 1998). On balance, high-fat meals appear to increase subsequent fatigue

and reduced reported alterness, but with little effect on cognitive performance, relative to high-CHO-low-fat meals. Lloyd *et al,* (1994) showed that optimal performance was seen with a medium-fat-medium-CHO lunch, whereas higher proportions of either fat or CHO caused subjects to be more drowsy, uncertain and muddled impairing cognitive efficiency. In a similar study but with breakfasts (Lloydd *et al.*, 1996), scores on a 'fatigue-dysphoria' mood factor were reduced after a low-fat-high-CHO breakfast. Given that these subjects' habitual lunch was probably medium-fat and their typical breakfasts closer to the low-fat-high-cho version, it seems plausible that mood may be adversely affected by meals that differ substantially in macronutrient composition from habitual ones (Rogers and Lloyd 1994, Dye *et al.,* 2000), rather than by high- or low-fat *per se.* In the Lloyd studies, mood differences were detected as early as 30 mins after the meal, and so are unlikely to be due to changes in systemic nutritional state.

There is further evidence that any increase in fatigue directly related to fat is not likely to occur until the arrival of substantial amounts of fat into the duodenum 2-3 hrs later. Half an hour after low- or high-fat meals, alertness increased and sleepiness declined, whereas 2.5-3 hrs later fatigue increased while arousal declined to the greatest extent after a high-fat meal (Wells *et al.,* 1995, 1997, Wells and Read, 1996). When lipid was infused directly into the duodenum, a decline in alertness was apparent much earlier, by 30-90 min after the meal there was an increase in fatigue and reduction in vigour after a high-fat meal when eaten mid-morning but not at lunchtime (Wells *et al.,* 1995, Wells and Read 1996). This could reflect either circadian effects or changes from habitual eating patterns. Nevertheless, on a sustained attention task, both speed and accuracy declined more rapidly after lipid infusion compared with saline, and after a high-fat versus low-fat midday meal (Wells *et al.*, 1995).

Ingested fat may alter mood or mental performance via the action of gastrointestinal and metabolic hormones. Cholecystokinin (CCK) (the gastric regulatory hormone) is particularly sensitive to increases in duodenal non-esterified fatty acids from the

breakdown of dietary fat (Schwizer *et al.,* 1997); moreover, exogenous CCK can reduce arousal as well as appetitive responses to meal preparation (Stacher , 1985). Wells *et al.* (1997) found that plasma levels of CCK and somatostatin increased to a greater extent after a high-fat, low-CHO (74%, 19%, respectively) than after a low-fat,high-CHO (11%, 81%), equi-energetic meal, whereas the reverse was true for insulin and glucose. Possible associations between levels of hormones and mood were examined. Levels of fatigue were positively related to CCK but negatively to gastrin levels. Sleepiness was positively related to insulin, but negatively to gastrin. However there were no interactions with meal types. The negative correlations between gastrin and fatigue sleepiness may reflect less fatigue-sleepiness in more anxious subjects (Wells *et al.,* 1997), since trait anxiety has been associated with higher gastrin levels (Uvans-Moberg *et al.*, 1993). It is therefore, not clear, though still a possibility that the differential effects of meal composition on hormones such as CCK underlie meal specific changes in mood.

1.6.1.5 Factors Influencing the Effects of Macronutrients On Mental Performance

In the studies reviewed there are many methodological differences and various factors which may have a moderating effect on performance have not always been considered. These factors have been discussed below.

Time of Day and Circadian Rhythms

The effect that macronutrients have on mental performance seems to be dependent on the time of ingestion. This is particulary relevant to carbohydrate. Lloyd *et al.* (1996) failed to find differences in objective performance after breakfasts with low-,medium-, or high-CHO content but did find that the high-CHO breakfast improved mood by reducing fatigue and dysphoria. In contrast, high-CHO lunches produced greater impairment of performance on attention and reaction-time tasks than did standard high-fat meals (Simonson 1948), high-protein meals (Spring *et al.,* 1983) or no lunch at all (Smith *et al.,* 1986). Performance on sustained-attention tasks is impaired in the early afternoon compared with late morning irrespective of food consumption (Spring *et al.,* 1983). A

review of 6 studies examining circadian rhythms in mental performance (Monk *et al.*, 1985) reported evidence of a deficit in performance in the early afternoon. Greater glucose responses indicating a poorer meal tolerance occur in the evening rather than the morning. Fasting blood glucose shows an opposite diurnal variation with higher levels in the morning rather than the evening. This could contribute to the effects of energy observed early in the day.

1.7 Type of Cognitive Performance Task

Another factor to take into consideration is the type of task used in the testing. A large number of mental or cognitive tasks are potentially able to demonstrate the effects of foods on performance. In practice however, a limited number of tests have been used. Some of the more frequently used ones are selected below (see table 1.f).

Table 1. f The Type of Functions assessed by cognitive tests

Function	Example of Tests	Common component of task
Vigilance (also known as sustained attention), rapid information processing, or continous performance	Search tests, e.g. categoric search, Digit symbol substitution (Coding), Stroop	Detection of stimulus items from particular categories The subject must replace Digits with symbols Subject must attend to certain features of stimuli and ignore others
Visual information processing Reaction time (decision and movement time)	Critical flicker fusion threshold Simple or choice	Subject must detect flicker and fusion of light Stimulus appears (visual or auditory) and subject must make a single response, usually by depressing a key; in the choice reaction-time test, one of a number of stimuli make appear and the subject must make one of two responses (e.g. left or right hand)
Frontal executive	Immediate recall e.g Digit Span	Subject is shown a list of stimuli at a given rate (e.g., one per second); at the end of the presentation the subject must recall the stimuli
Working memory (short-term memory)	Verbal memory Spatial memory Associative memory Word recognition Pattern comparison	 Subjects must recognize rather than recall the stimuli Subjects must descriminate or recognize patterns
Immediate memory	Digit Span	Subject must remember (recall) series of items in forward or reverse order
Reasoning	Arithmetic, logical, grammatical, or semantic	Subject must process and indicate whether stimulus is true or false
Psychomotor performance	Pursuit rotor	Subjects must trace a shape (maze) with a stylus under time pressure; error score is computed
Visuospatial motor task	Simulator or driving task Tapping task	 Subject must tap in rapid succession to a key

The nature of the task is crucial, with tasks requiring sustained attention most sensitive to meal effects (Smith *et al.*, 1992). Some studies have shown attention to be a sensitive measure and others reaction time. Consideration of the nature of the tasks frequently used demonstrates that many actually involve time to detect a signal and therefore could be

considered tasks of attention, although the dependable variable is reaction time. Few cognitive tasks in this field allow separation of detection and response time. A lack of effect on some tasks could be from a subtle effect of a micronutrient on only one component of the task. Many studies have administered "off-the-shelf" tests in a test battery. In the selection of tests careful consideration of the cognitive and neuropsychological faculties that the tests measure and the specific functions they unravel need to be taken into consideration (Dye *et al.,* 2000). Cognitive tests employed thus so far in studies of this kind are often too short a duration. It is not possible to determine whether functions are enhanced or whether better performance simply reflects an increase in the ability to sustain performance or attention on indiscriminately selected test batteries. Another crucial factor to consider is the size of the cognitive load. In many of the nutritional effects the demands of the task (the cognitive load) are unknown. There are a number of physiological changes in response to mental effort including an increased heart rate, which facilitates the delivery of extra glucose and oxygen to the brain. An increases heart rate should accompany task with a high degree on mental effort (Kennedy *et al.,* 2000). Few studies however have recorded this.

One of the most widely used battery of tests is the Wechsler Intelligence Scale which is available for both adults and children. The scale for children has been discussed below.

1.7.1 The Wechsler Intelligence Scale for Children –Third Edition UK (WISC-III^{UK})

The (WISC-III^{UK}) is an individually administered clinical instrument for assessing the individually administered clinical instrument for assessing the intellectual ability of children aged from 6 years through to 16 years, 11 months. It is the second revision of the Wechsler Intelligence Scale for Children (WISC;Wechsler 1949). Although it retains the essential features of earlier editions, the WISC- III^{UK} provides updated test materials, test content and administration procedures, and current normative reference points based on a UK validation programme. The WISC-III ^{UK} consists of several subtest, each measuring a

different facet of intelligence. The child's performance on these various measures is summarised in 3 composite scores, the Verbal, Performance and Full Scale IQs, which provides estimates of the individual's intellectual abilities. There are also 4-optional-based index scores.

Wechsler's Conception of Intelligence

Wechsler viewed intelligence not as a particular ability but as an aggregate and global entity, the "capacity of the individual to act purposefully, to think rationally and to deal effectively with his or her environment." The subtests of the WISC-III ^{UK} have been selected to tap many different mental abilities, which all together indicate a child's general intellectual ability. Some subtests require the child to reason abstractly, some focus on the child's memory, some call for certain perceptual skills and so on. All of these abilities are valued to varying degrees by our culture and all relate to behaviour that is generally accepted as intelligent in one way or another. No single subtest is intended to provide an adequate index of intelligent behaviour. The Wechsler scales probe intellectual functioning in many ways, with subtest that measure performance on many different tasks, allowing varied opportunities for children to display their particular abilities.

Applications of the WISC-III ^{UK}

The WISC-III ^{UK} is useful and appropriate for a number of purposes. These include psychological assessment contributing to;

1) educational planning
2) resource provision and placement decisions
3) identification of unusual cognitive profiles relating to exceptional ability or learning difficulties among school-aged children
4) clinical and neuro-psychological assessment and research

Subtests of the WISC-III, WISC-R and WISC-III^{UK} have been used in several studies looking at nutrient intake and performance (Bellisle *et al.,* 1998). The individual WISC-III^{UK} subtests measure the functions described in tables 1.r a and1.rb

Organisation of the Scale

The WISC-III^{UK} comprises 13 subsets. Tables 1.g and 1.h lists the WISC-III^{UK} subtests, provides a brief description of each and the function assessed.

Table 1.g Descriptions of the Verbal WISC- III^{UK} subtests

Subtest	Description	Specific Abilities
Verbal		
Information	A series of orally presented questions tap the child's knowledge about common events, objects, places and people.	Range of general factual knowledge
Similarities	A series of orally presented pairs of words for which then child explains the similarity of the everyday objects or concepts they represent.	Logical abstractive (categorical thinking)
Arithmetic	A series of arithmetic problems which the child solves mentally and responds to orally.	Computational skill
Vocabulary	A series of words presented orally which the child defines	Language development Word knowledge
Comprehension	A series of orally presented questions that require the child to solve everyday problems or to show understanding of social rules and concepts.	Demonstration of practical information Evaluation and use of past experience Knowledge of conventional standards of behaviour
Digit Span	A series of orally presented number sequences which the child repeats verbatim for Digits Forward and in reverse order for Digits Backward.	Immediate auditory memory

Table 1. h Descriptions of the Performance WISC- III^{UK} subtests

Performance		
Picture Completion	A set of colourful pictures of common objects and scenes each of which is missing an important part which the child identifies.	Visual recognition identification (long-term visual memory)
Coding	A series of simple shapes (Coding A) or numbers (Coding B) each paired with a simple symbol. The child draws the symbol in its corresponding shape (Coding A) or under its corresponding number (Coding B)	Sustained attention and psychomotor speed
Picture Arrangement	A set of colourful pictures, presented in mixed-up order, which the child rearranges into a logical story sequence.	Anticipation of consequences Temporal sequencing and time concepts
Block Design	A set of modelled or printed two-dimensional geometric patterns which the child replicates using two-colour cubes	Analysis of whole into component parts Nonverbal concept formation
Object Assembly	A set of jig-saw puzzles, each presented in a standardized configuration, which the child assembles to form a meaningful whole.	Ability to benefit from sensory-motor feedback
Symbol Search	A series of paired groups of symbols, each pair consisting of a target group and a search group. The child scans the two groups and indicates whether or not a target symbol appears in the search group.	Speed of visual search
Mazes	A set of increasingly difficult mazes.	

The WISC-III^{UK} subtests are then grouped into either the verbal or performance scales.

Table 1.i The Verbal and Performance Subsets of the WISC-III ^{UK}

Verbal	Performance
2 Information	1 Picture Completion
4 Similarities	3 Coding
6 Arithmetic	5 Picture Arrangement
8 Vocabulary	7 Block Design
10 Comprehension	9 Object Assembly
12 Digit Span	11 Symbol Search
	13 Mazes

In addition to the Verbal and Performance and Full Scale IQs, 4 factor-based index scores can be calculated: (1) Verbal Comprehension (VCI) (2) Perceptual Organisation (POI) (3) Freedom from Distractibility (FDI) and (4) Processing Speed (PSI).

Table1.j Scales derived from factor analyses of WISC-III^{UK} subtests

Factor I	Factor II	Factor III	Factor IV
Information	Picture Completion	Arithmetic	Coding
Similarities	Picture Arrangement	Digit Span	Symbol Search
Vocabulary	Block Design		
Comprehension	Object Assembly		

The third and fourth factors are small, composed of just 2 subtests a piece, yet these 2 factors are important. The 3rd and 4th factor are important because they allow the systematic evaluation of a child's verbal and non-verbal abilities by allowing the researcher to subdivide each scale into two meaningful components. The main plus however is the clinical flavour of the subtests that compose Factors 3 and 4.

The Freedom from Distractibility (FD) factor is controversial and is the occasional subject of philosophical debate. Research has shown, performance on the subtests that define the distractibility factor is greatly facilitated by attention and concentration, whereas it is impaired by distractibility and anxiety (Beck and Spruill 1987, Lufi and Cohen 1985, Lutey 1977, Wielkiewicz 1990), and it is related to motivational problems in school (Holcomb, Hardesty, Adams and Ponder 1987) and to somatic complaints (Dollinger, Goh and Cody 1984). As such the FD factor has been used as a clinical indicator of ADHD

(Barkley, 1990); however, a variety of studies have questioned its validity for this purpose (Cohen, Becker and Campbell, 1990, Kampus 1993, Kostura 1993 and Stone 1992). Whilst the debate for its use as an indicator or ADHD remains questionable, there is an association between the FD factor and measures of both auditory/verbal and visual/spatial immediate/working memory (Riccio *et al.*, 1997).

The Information –Processing Model

The information processing model proposed by Silver (1993) provides a conceptual framework for interpreting IQs, Factor Indexes, and scales scores that extends beyond the specific scores obtained.

The basic model has 4 components:

1. *Input* How information from the sense organs enters the brain
2. *Integration* Interpreting and processing the information
3. *Storage* Storing the information for later retrieval
4. *Output* Expressing information via language or muscle activity

Regarding input, the WISC-III^{uk} Verbal subtests tend to be auditory and the Performance tasks visual. The integration component addresses the fact that different mental tasks demand different cognitive processes for success. Similarities, Comprehension, Arithmetic, Picture Arrangement, and Object Assembly call on reasoning and problem solving; Block Design, Digit Span, and Coding require imitation of a model. Similarly, the storage requirements differ from task to task. Digit Span, Coding and Symbol Search measure the ability to store information for a brief time, whereas Information and Vocabulary require children to retrieve facts and concepts from long-term store. Indeed, all problem solving tasks on the WISC-III^{UK} involve what cognitive psychologists refer to as working memory (Kolligan and Sternberg, 1987, Vernon and Jenson, 1984) (see Figure 1.d for most recent model) (Baddeley, 2000) which reflects the reciprocal nature of storage and mental processing: Information that is taken in or encoded long enough to allow the

person to identify the strategies needed to solve the problem; to some extent, retention and processing must occur simultaneously.

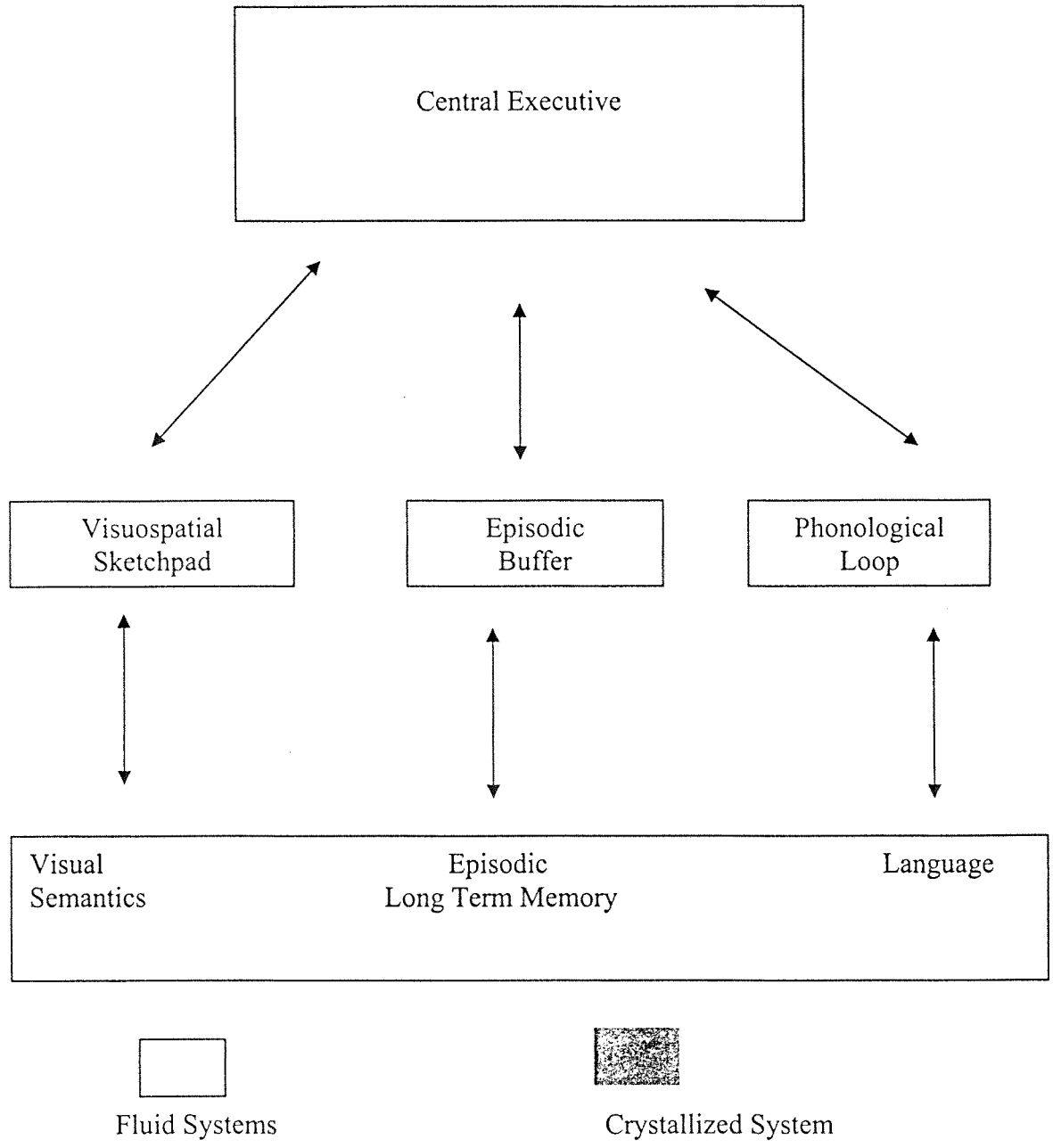


Figure 1.g The Current Model of Working Memory, Revised to Incorporate Links With Long-Term Memory (LTM) By Way of Both the Subsystems and the Newly Proposed Episodic Buffer

Baddeley and Hitch (1974) proposed that working memory is a three component system with a limited capacity attentional controller, the central executive, aided by two subsystems, one concerned with acoustic and verbal information, the phonological loop, and the other performing a similar function for visual and spatial information, the

visuospatial scratchpad. Since then the phonological and visuospatial subsystems have been extensively investigated, leading to more detailed attempts to model the processes underlying the subsystems. The central executive is now thought to be aided by a episodic buffer which is an interface between the central executive and long-term memory.

The output mode is basically vocal for the Verbal subtests and motor for Performance subtests. The tasks differ in terms of the amount of output required.

Horn and Cattell's Fluid –Crystallized Theory

Horn and Cattell (1966) distinguished between two broad constructs, Crystallized Intelligence (Gc) and Fluid Intelligence (Gf). Gc reflects problem solving and factual learning that is dependent on formal schooling and acculturation, whereas Gf refers to the ability to solve new problems where neither formal schooling nor acculturation facilitate task performance to any meaningful extent (Cattell and Horn, 1978). Horn further identified "purer" cognitive measures of intelligence, and proposed a further eight abilities. Some of these additional abilities include Short-Term Acquisition and Retrieval (SAR or GSM), Broad Speediness (Gs), Broad Visualization (Gv), Quantitative Thinking (Gq), and Auditory Intelligence.

The WISC-III subtests as Gc and Gf are shown here, followed by groupings of subtests into other Horn factors.

Crystallized Intelligence (Gc)	Fluid Intelligence (Gf)
Information	Picture Arrangement
Similarities	Block Design
Vocabulary	Object Assembly
Comprehension	Similarities
Picture Arrangement	Arithmetic

Broad Visualization (Gv) include "tasks that call for fluent visual scanning, mind's eye rotations of figures, and ability to see reversals."

e.g. Picture Completion, Block Design, Object Assembly

Short-Term Acquisition and Retrieval (SAR) are similar to sequential processing or information. SAR or Gsm "involves processes of becoming aware of information, discriminating between different bits of information, retaining such awareness and discriminations for short periods of time, using these awareness's and discriminations..... in performing various kinds of tasks."

e.g. Arithmetic, Digit Span

Broad Speediness (Gs) "Speediness in intellectual tasks relates to carefulness, strategies, mood and persistence."

e.g. Coding, Symbol Search, Object Assembly

There are a number of tests that have been used to disclose the effects of foods. Two well known WISC-III subtests that have been used is the Digit Span and Coding scores which have been discussed below.

The Digit Span Test (Forward and Backward Digit Span)

Cognitive psychologists (Jensen and Figueroa, 1974) and neuropsychologists (Costa, 1975) have known for decades that Wechsler's Digits Forward and Digits Backward measure a different set of skills. Repeating digits in the same order they are spoken is an automatic task that requires an immediate response with some mediation (chunking numbers), and does not tax the individual's working memory. Reversing digits, requires manipulation and spatial visualization to recode the information in working memory; it requires representational thinking and is not an automatic task. Repeating digits in their reverse order is related to the visual-spatial ability of brain damaged individuals and is impeded by right hemisphere damage, but repeating digits forward is not (Costa 1975, Weinberg, Diller, Gerstman and Schulman, 1972). Reversing digits seems to involve the formation of an internal visual representation of the information received auditorally (Gardner 1981), and measures different abilities than repeating digits forward (Talley, 1986). Research suggests that Digits Forward assesses sequential or successive processing whereas Digits Backward measures both successive processing and planning ability

(Schofield and Ashman, 1981). Despite the well –known cognitive and neuropsychological distinction between the two halves of Digit Span, the Wechsler scales provide a single score based on their combination. Wechsler chose digit span as a short-term memory task, noting that this was one of the abilities of which a " certain absolute minimum" seems necessary for school achievement (Wechsler, 1939).

The Coding Test

Another of the subtests which has been used in nutrient and cognitive function test it's the symbol substitution test which is called the Coding subtest of the WISC-III^{uk} test. Coding is known to be sensitive to neurological dysfunction (Smith, 1975), so a low coding score is compatible with the idea that dyslexia is the result of deviant central nervous system development (Benton, 1975). To determine the skills measured by the Coding subtest, Lyle and Johnson (1973, 1974, Johnson an Lyle, 1972a, 1972b, 1973) contrasted good and poor Coders whose reading ability was unmeasured. They found that Coding performance to be related to speed of writing, recall of the Coding symbols and their associates, and speed of paired-associate learning on an independent task. Writing speed and associative learning were significant predictors of Coding scores. The Coding score has a high cognitive load in that large the psychomotor speed needed to score well in this test is high.

1.8 Food, Mood and Behaviour

It is a common perception amongst the public that diet affects behaviour. (Behaviour refers here to the social and emotional dimension of behaviour). There was an explosion of scientific research and interest in this area in the 1980s, in part because of evidence that the brain is more sensitive to nutrient supply than previously thought (Anderson *et al.*, 1983). There has been much interest in the affect of carbohydrate and mood and behaviour as compared to protein and fat, and also the affect on fasting on behaviour. Breakfast studies have shown that alertness was found to increase after a high-CHO meal versus a high-fat meal (Holt *et al.*, 1999) and Smith found that fatigue was decreased after

a high fibre breakfast (Smith *et al.*, 2001). In another set of experiments Smith found that subjects were happier after a cooked breakfast as compared to a high-CHO breakfast (Smith *et al.*, 1994). Below is a discussion of the mechanisms by which that CHO, protein and fat may effect behaviour. Whilst there are other areas of interest in this field these are not within the parameters of the present research.

1.8.1 Carbohydrate Versus Protein

The hypothesis by Wurtman and colleagues linking carbohydrate and protein intake, brain sertonergic (5-hydroxytrptamin, 5-HT) function on mood and behaviour is the most extensively tested idea looking at the relationship of food and mood (Rogers *et al.*, 1995).

This research was based on the results of studies carried out mainly in rats (Wurtman *et al.*, 1981). Here it was proposed that a high CHO meal increases the ratio of the plasma concentration of tryptophan (TRP) relative to the other 'large neutral amino acids' (TRP:LNAA).This occurs because insulin released in response to the CHO load helps the uptake of most amino acids but not (TRP), into the peripheral tissues. Uniquely for amino acids, TRP is bound to albumin in the blood stream, and the affinity for TRP actually increases in response to insulin as free fatty acids (FFA) are stripped off the circulating albumin (owing to the effect of insulin on the removal of FFA from the circulation). TRP is the precursor of the neurotransmitter serotonin. Since TRP and the other LNAA compete for entry into the brain and the rate limiting enzyme for serotonin production (trptophan hydroxylase) is not fully saturated with substrate under normal conditions, an increase in plasma TRP:LNAA concentration leads to an increase in brain serotonin sythesis an , in turn, to increased serotonergic neurotransmission. In contrast, consumption of a meal high in protein can be expected to have the opposite effect, primarily because most dietary proteins contain little tryptophan (Wurtman *et al.*, 1981).

Behavioural consequences from these diet induced changes in neurotransmission have been shown to demonstrate altered food choice and intakes in humans, along with changes in pain sensitivity, aggressiveness, mood, alertness and cognitive performance (Rogers *et al.*, 1995). The increase in brain serotonergic activity occurring after a high CHO v. high protein meal is hypothesized to give rise to, decreased alertness and a decline in performance (Spring *et al.,,* 1971 and Young , 1991). This contradicts the popular perception that CHO, especially sugar, will have an energising or even hyperactive effect.The evidence for the sertonergic effect of CHO is mixed. Several studies showed that there was greater drowsiness, sleepiness and calmness after CHO-rich meals compared with protein rich meals (Spring *et al.,* 1987). However this was not consistent across the subject groups. Other studies in the last 1980s and early 1990s however failed to show any definite CHO versus protein effects on mood, despite confirmation of the significant effects on TRP: LNAA (Deijen *et al.,* 1989, Christensen and Redig., 1993). A sugar sweetened drink was found to increase sleepiness and decrease alertness when compared to a drink sweetened with aspartame (Pivonka and Grunewald, 1990), whilst other studies did not show such clear results (Brody and Wolitzy, 1983). However Rogers and Lloyd (1994) reviewed this topic and found that contrary to the predication of the CHO-serotonin hypothesis, performance is in general improved after consuming a glucose drink in comparison to a non-nutrient containing control drink.

1.8.2 Carbohydrate and Fat

The role of fat intake on mood and performance has more recently been the focus of interest. In these experiments protein levels were kept constant whilst fat and carbohydrate levels were varied. Low-fat (e.g. 11-29% of energy from fat), medium fat (e.g. 45%) and high-fat (e.g. 56-74%) breakfasts, mid-morning and midday meals have been have been

compared (Lloyd *et al.*, 1994, 1996; Wells and Read 1996; Wells *et al.*, 1997). The effects of intraduodenal infusions of lipid or saline (Wells *et al.*, 1995) have also been investigated.

Overall, high-fat meals have been shown to increase fatigue and reduce alertness. There appears to be only a small effect on cognitive performance as compared to high carbohydrate-low-fat meals. There were however inconsistencies in these findings, e.g. feelings of drowsiness, confusion and uncertainty increased after low- and high-fat lunches but not after a medium-fat lunch (Lloyd *et al.*, 1994). A post lunch improvement in reaction time was seen after the medium-fat but not the low- or high lunches, but other performance measures were not affected. The breakfast study that Lloyd performed which looked at different amounts of fat in the breakfast meal on mood, showed that 'fatigue-dysphoria' mood factor were reduced after a low-fat-high- carbohydrate breakfast (Lloyd *et al.*, 1996). This could be due to the fact that mood may be affected by meals that differ substantially in macronutrient composition from habitual ones (Rogers and Lloyd, 1994; Dye *et al.*, 2000), i.e. subjects were habitually eating a low-fat breakfast and the change from a low-fat to a different breakfast may change their mood rather than high- or low-fat *per se.*

Mood differences were seen in the Lloyd studies after only 30 mins (Lloyd *et al.*, 1994, 1996) however there is evidence to show that increases in fatigue because of fat ingestion are not likely to occur until the arrival of substantial amounts of fat into the duodenum 2-3 h later (Wells *et al.*, 1995, 1997; Wells and Read, 1996). It is possible therefore in Lloyd's studies that the effects of mood may have resulted from discrepancies between subjects' expectations of post-ingestive effects, and the actual effects that resulted from neurohormonal responses to detection of specific nutrients in the duodenum and liver (Wells *et al.*, 1995, 1998).

Wells and Read showed that half an hour after low- or high-fat meals, alertness increased and sleepiness declined and arousal declined to the highest extent 2.5-3h after a high-fat

meal (Wells *et al.,* 1995, 1997; Wells and Read, 1996). If lipid was infused directly into the duodenum, alertness declined much earlier. There was a increase in fatigue and reduction in vigour by 30-90 mins after a high fat-meal when eaten mid morning but not at lunch time (Wells *et al.,* 1995).

An increase in fatigue and reduction in vigour was observed after a high fat meal when eaten mid morning but not at lunchtime. (Wells and Read, 1996). This could reflect either circadian effects or changes in habitual eating patterns. However a the decline in the speed and accuracy of a sustained attention task declined more rapidly after a lipid infusion and after a high-fat v. low-fat midday meal when compared with saline (Wells *et al.,* 1995).

In a more recent study by Fischer *et al.,* (2001) however have showed that memory attention and choice reaction time improved after high fat ingestion as compared to protein or CHO ingestion. In these experiments subjects ate 400kcal of either fat, protein of CHO, in the form of sweet vanilla creams to disguise sensory differences. The improved performance after fat ingestion was demonstrated to be due to the lack of glycaemic and hormonal disturbances (i.e. no release of insulin, glucagons and cortisol). However there was also an effect of the arousing effect of protein relative to CHO also.

The mechanisms behind which fat might effect mood and performance is via the action of metabolic and gastrointestinal hormones. Cholecystokinin (CCK) which is a gastric regulatory hormone is affected by the breakdown of dietary fat which leads to increases in duodenal non-esterified fatty acids (Schwizer *et al.,* 1997). CCK can reduce arousal (Stacher, 1985). Plasma CCK level and somatostatin increase to a great extent after a high-fat, low –CHO than after a low fat, high- CHO equi-energtic meal. The reverse was true for insulin and glucose. There was an increase in gastrin in equal amounts after both meals. Associations between levels of hormones were investigated by multiple regression. Fatigue was positively correlated to levels of CCK and negatively with gastrin whilst sleepiness was positively related to insulin and negatively to gastrin. However there were no interaction of meal types in the regression analyses, and changes in gastrin were

unrelated to meal type. Trait anxiety has been associated with higher gastrin levels (Uvnas-Moberg *et al.*, 1993) and Wells *et al.*, (1997) suggested that the negative correlations between gastrin and fatigue- sleepiness may reflect less fatigue-sleepiness. Therefore it's not clear whether meal composition on hormones such as CCK are responsible for changes in mood.

1.8.3 Measuring Behaviour

There are many questionnaires used to measure mood and behaviour in adults and many of these are self assessed. This is not possible for measuring behaviour in children and for this reason questionnaires have been developed for parents to measure their child's behaviour at home and for teachers to measure this at school. Whilst parents are typically the most important adults in children's lives, teachers have several unique qualifications for describing children's functioning. They observe and interact with children in a more-or-less standardized social environment and can make direct comparisons among children of the same developmental level (Edelbrock and Achenbach , 1984). Since school is a major arena for social interactions among children, teachers are in an excellent position to observe children's social skills and peer relations. In addition, teachers are in an exceptionally good position to observe children's responses to tasks that require sustained attention, persistence, and organization.

Authors who have researched the effect of breakfast omission on behaviour have concluded that breakfast has prevented the negative behaviour associated with hunger (Koonce 1972, Pinkus, 1970, Keister, 1950 and Laird, 1931). More recently the Community Childhood Hunger Identification Project (CCHIP) in the U.S has shown that hunger is associated with poor behavioural and psychosocial behaviour in children (Kleinman *et al.*, 1998 and Murphy *et al.*, 1998a). This is not an unexpected finding, however few studies have looked at the effect of different types of breakfast on behaviour in children. Two exceptions to this are the studies by Murphy *et al.* (1998b) and

Worobey and Worobey (1996) who have shown that children who eat a SBP breakfast show better behaviour than children who eat breakfast at home.

There are many methods of assessing children's social/emotional behaviour, due to professional interest in the field of child psychology (Lindeman *et al.,* 1990). Among these measures are direct observation, mechanical devices that measure frequency of movement, rating scales and checklists. Behaviour rating scales are most frequently used in both classroom and clinical setting , because they are accurate, inexpensive and easy to use. Many rating scales have been designed specifically for use by teachers in the classroom. Deciding which behaviour rating scale to use essentially depends upon what behaviours the researcher wishes to observe. The researcher must bear in mind that cooperation of the teacher (behaviour rater) will affect the scale of choice, If the scale is too long, the questions too abstract or the rating of each behaviour item too limited (dichotomous), the teachers may hesitate to participate (Edelbrock, 1983).

Three commonly used behaviour rating scales have forms designed for classroom observations. All have normative data and reliability established. The Child Behaviour Profile by Edelbrock and Achenbach (Edelbrook and Achenbach, 1984), a 118-item behaviour rating scale identifies problems with anxiety, social withdrawal, self – destructiveness, nervousness and aggression. The Behaviour Checklist by Quay (Quay, 1983), an 89-item checklist, describes six personality traits of children: conduct problem, personality problem (anxiety-withdrawal), inadequacy-immaturity, socialized aggression, psychotic behaviour and motor excess. The Conners Teacher Rating Scale (TRS) is a 28-item questionnaire designed to aid teachers identify hyperactive children and it has been examined as a tool for measuring the relationship between food and behaviour in children (Conners *et al.,* 1982, Achenbach, 1978, Werry *et al.,* 1971, Conners, 1969, Touliatos, 1975 and Glow, 1982).Studies by Murphy *et al.* (1998b) and Worobey and Worobey (1996) have shown that children who eat a SBP breakfast show better behaviour than children who eat breakfast at home.

1.9 Nutrient Intake and Growth In Children

The hypothesis on page (figure 1.q)shows the possible link between breakfast and nutrient intake and how this in turn may have an effect on growth and nutritional status. Only a few studies have shown an improvement in children's nutritional status by way of a increase in growth velocity with school feeding and these are in developing countries where improved nutrient status has had a positive effect on growth in undernourished children (Grantham-McGregor *et al.,* 1998 Paige *et al.,* 1976, Argarwal *et al.,* 1987, Lancet *et al.,* 1928, Leighton *et al.,* 1929, Lininger *et al.,* 1933). There has been no such evidence in well nourished populations.

1.9.1 Measures Of Growth

Tanner described height as the single best index of growth (Tanner *et al,* 1986). If weight is measured at the same time, three important indicators of nutritional status can be estimated; weight for age, height for age and weight for height (WHO, 1979.) Weight or height for age shows how closely an individual or population group conforms to standards for a particular age. The weight for height index identifies individuals who demonstrate signs of under nutrition or obesity. This index has limitations since it cannot distinguish between individuals who are large due to fatness or those who are very muscular (Garrow, 1983). The body mass index (BMI) proposed for adults(weight/height^2; Quetelet, 1869) can provide us with an estimation of adiposity. However the use of this may not be suitable for children (Norgan, 1990) since the relationship between height, weight and corpulence alters with increasing age and so prevents the use of extrapolations. The use of different age range was suggested by Traub and Kichen (1983). Cole (1991) however supported the use of BMI in primary school children because of a better correlation with body fat than other indices. Indeed in the late 1990s BMI adjusted for age became a popular method for measuring child obesity (Cole *et al.*, 1995, Dietz and Robinson, 1998).

Height, weight and BMI of any group of subjects can be compared to UK population standards for height, weight, BMI. The standards were revised in 1990 and were published

in 1995 (Freeman *et al.,* 1995) and have replaced Tanner's 1966 height and weight standards (Tanner *et al.,* 1966). The 1990 standards also include BMI which the previous 1966 sample did not. Height, weight and BMI can be expressed as the standard deviation scores (SDS) of the new population standards. SDS express measurements as the distance in standard deviations from a population mean, appropriate to the decimal age and sex of each individual. SDS of individuals can be manipulated into group means and standard deviations thus making comparisons between groups, e.g. those based on dietary intake, more meaningful since variation due to sex and age does not have to be accounted for (Smith and Booth, 1989). The SDS centile for weight, height and BMI can also be calculated Paediatric BMI centile charts have been in existence since 1995 and is still a relatively new area in clinical practise (Eldridge, 2002).

These methods are valuable tools for researchers investigating growth and allow comparisons with UK standards. However it is highly unlikely that a group of rural primary school children in Falkirk (n=113) will show relevant or meaningful comparisons with the UK population standard sample. Also the aims of the present study are to look at the difference between children eating breakfast at school (BC) in a breakfast club to those who eat breakfast at home (HB). It is therefore the focus to look at the difference between these two group in terms of height, weight and BMI and height and weight velocity.

1.9.2 Height and Weight Velocity

Height and weight gives a 'snap shot' of growth. Growth velocity and height velocity is of major importance when one of the aims of a study is to relate dietary intake to growth. At birth growth velocity is at it's highest and decreases gradually until adulthood. Whilst there is a definite increase in growth velocity at puberty another mid-growth spurt may occur between 6 and 8 years (Molinari *et al.*, 1980) although this is thought not to occur in all children (Tanner and Cameron, 1980). Marshall (1971) found that there were seasonal variations in growth velocity where growth is slightly faster in Spring and slower in Autumn.

A reasonable time to measure growth velocity is between 6 to 12 months. Where the effect of nutrition on growth is being investigated a cross-sectional study design will mask intra-individual changes in growth velocity (Tanner , 1986). A longitudinal study however, where the same group of children are followed up will allow dietary influences to be investigated.

1.9.3 Studies on Growth and Anthropometry

In developed countries children are getting taller and heavier with each generation (Tremblay and Williams, 2000 and Freedman *et al.,* 2000). Indeed children in England and Scotland are becoming taller for a given age (Hughes *et al.,* 1997). The National Study of Health and Growth (NSHG) was a major ongoing British longitudinal surveillance study which began in 1972. This study looked at growth in primary school children . Chinn and Rona (1984) who collected data from 29,230 children found that the secular increase in height for primary school children as reported previously by Tanner (1973) in the first surveillance. Little change was found in the prevalence of overweight or obesity from 1974 to 1984 . Height of English children in most age groups increased by more than 1 cm and by more than 2 cm in Scotland during the period 1972 to 1994 (Hughes *et al.,* 1997). From 1984 to 1994 overweight increased from 5.4% to 9.0% in English boys and from 6.4% to 10.0% in Scottish boys (3.6%, 1.9% to 5.4%). Values for girls were 9.3% to 13. 5% and 10.4% to 15.8% respectively. The prevalence of obesity increased correspondingly, reaching 1.7% (English boys) 2.1% (Scottish boys), 2.6% (English girls), and 3.2% (Scottish girls) (Chinn and Rona, 2001). Height of English children in most age groups increased by more than 1 cm and by more. As compared to the English group Scottish school children were significantly shorter. Also measurement of body fat showed that there was an increase in both groups but fatness was slightly higher in the Scottish group. The authors suggested that this indicated a trend towards obesity in Scottish school children particularly.

Exploring obesity in children is not within the parameters of the thesis. However the type of breakfast served at school may have an impact on dietary intake for the day. This in turn may influence weight gain in children. If Scottish children have been described as an at risk group, the meals that eat at school should be healthy, nutritious and in-line with government recommendations for healthy eating.

1.9.3 Studies on Growth and Anthropometry

For many years growth has been used as an indicator of nutritional status in children (Tanner, 1986). In developing countries where malnourishment and undernutrition are evident, dietary interventions have of course had a positive impact on growth. Few studies that have investigated well nourished populations have found strong relationships between growth and dietary intake. For this reason researchers are divided on whether energy intake and nutrient intake has a direct effect on growth in these populations. Magarey and Boulton found that dietary effects on growth are only apparent in clinically deficient children (1987). Relationships between dietary intake and growth may only be apparent in children who have nutrient and energy intakes below the nutritional requirements for growth and maintenance. It is therefore reasonable to expect either a poor or no relationship between dietary intake and growth in children who have nutrient and energy intakes above that required for normal growth.Breakfast studies have found no relationships between growth and dietary intake in well nourished populations. Growth rates are thought to be cyclical (Butler *et al.*, 1990) and whilst dietary and breakfast surveys have found no relationship between dietary intake and growth it may be that the window of time when nutrients might affect growth were missed in the investigative period. Widdowson said that she was unable to 'bring to light the laws which relate height, weight, size and surface area of any one person to his calories intake or calorie requirement' (Widdowson, 1947) and it appears that if we are still not enlightened after almost 60 years of research.

1.9.5 Measuring Body Composition

Body composition is a far more complex measurement than height and weight. Techniques have been developed in order to measure body composition and are often validated against other more established methods. However this is always some degree of error since no single method can be described as the 'gold standard'. Nevertheless there are a number of indirect methods that researchers use today. The choice of method is dependent on cost, facilities and acceptability to the subject. This last factor is extremely important when considering measuring body composition in children. Whilst there is no error free method of measuring body composition, the most accurate indirect method to date has been densitometry. It is regarded as the reference method for the analysis of body composition and other methods for the measurements of body composition have been correlated against this. Densitometry has been estimated to have a theoretical error of 3-4% (Lohman *et al.,* 1981). This method determines body volume according to Archimedes' principle, which states that the volume of an object submerged in water equals the volume of water that the object displaces. The difference between measuring a mass in air and in water provides the body volume (factors such as lung volume and water temperature are all taken into consideration). Densitometry is widely perceived as impractical because of time, effort and acceptability to subjects and has not been a method that has been deemed acceptable for children.

One widely used method that has been used for the estimation of body fat is the measurement of skinfold thickness ,as described by Durnin and Rahaman in 1967. These researchers developed this technique to meet the need for a 'simple method of assessing punitively the fat content of the human body, which could be used not only in laboratories and in hospital, but in field studies and in general medical practice (Durbin and Brahman, 1967). In this method, callipers are used to measure the thickness of skin and subcutaneous adipose tissue at various sites of the body. It makes two assumptions; the thickness of subcutaneous adipose tissue is related to total body fat and the sites selected

for measurement represent the average thickness of the subcutaneous adipose (Lukaski, 1987). This procedure has been validated by comparing the logarithm of the sum of skinfold thickness to density as determined by densitometry. The equations for predicting density from skinfold thickness were determined by multiple regression analysis. Equations for predicting this in children have been reported by Brooke (1971) using the sum of four skinfolds: tricep, bicep, sub scapula and the iliac crest. Prediction equations using the tricep and sub scapula areas have been reported by Slaughter *et al.* (1988).

The main problem with this technique is that there is poor reproducibility and validity where inexperienced observers are concerned (Burkinshaw *et al.*, 1973) since the technique is highly observer –dependent (Lukaski, 1987). Less reproducible methods are evident in more obese subjects (Bray et al, 1978). Acceptable repeatability and validity however can be achieved within a relatively short period of training (Walker and Kindlen, 1988). Prior to collecting skinfold data on subjects, it is advisable that observers assess repeatability by measuring a group of subjects a number of times and obtaining an estimate of variation (<5% variation is acceptable). The issue of errors in technique is rarely addressed by authors reporting data on skinfold thicknesses (e.g. Cook *et al.*, 1975; Cronk and Roche, 1982; Harries *et al.*, 1983).

There are a number of errors associated with transforming skinfold data into a measure of fat. Error is introduced by assuming that the areas selected for measurement are proportional to total subcutaneous fat. Also the calculations used to transform raw data to body fat introduces a number of assumptions and it has been suggested that using untransformed data may be more accurate (Norgan, 1993). Another factor to consider is that the equations used to estimate density from skinfold thickness are based on small sample sizes which may make them specific to that population. Since the relationship between fat and fat free compartments in the body changes with age (Slaughter *et al.*, 1998) and so different equations for different group are unavoidable. Another equation is also required after density has been calculated in order to predict percentage body fat.

Siri's equation is often used but may not be suitable for children as it is based on adult figures for the proportion of total body water and bone within the body. Hence the Siri equation may overestimate density in a paediatric population (Norgan, 1990). Whilst this method has been used in school based studies (e.g. Ruxton *et al.,* 1996) it requires parental permission and agreement by the school who may perceive the method as too invasive.

Bioelectrical Impedence Analysis

A less invasive (Smith, 1993) and popular method for measuring body composition is bioelectrical impedence analysis (BIA). It is practical, comparatively inexpensive (Kushner *et al.*, 1990) and is reported to be precise and not observer-dependent (Richardson *et al.*, 1990). The technique has been validated in adults using densitometry (Segal *et al.*, 1988; Deurenberg *et al.*, 1989), total body potassium and isotope dilution (Richardson *et al.*, 1990, Walker *et al.*, 1993). In non pubertal children, BIA has been validated using isotope dilution (Davies *et al.*, 1988, Gregory *et al.*, 1991) and densitometry (Deurenberg *et al.*, 1991). BIA makes the assumption that tissue conductivity is proportional to the amount of lean tissue, since the water and electrolyte content is highly conductive. Bioelectrical impedence thus provides a measure of the mass and distribution of total body water (TBW) (Kushner and Schoeller , 1986). Once total body water is estimated, fat-free mass (lean body mass) can be ascertained by the assumption that fat-free mass is 73% water (Fuller *et al.*, 19920 and by subtracting lean body mass from total body weight, fat mass can be derived. Measuring total body water (TBW) may be a better indicator than measuring fat mass as it is the compartment in the body responsible for vital processes i.e. the metabolically active compartment in the body (Fearon *et al.,* 1992), making it a more sensitive measure of body composition and nutritional status.

BIA models are available with dual and single frequencies. In the duel frequency models the higher frequencies penetrate the cell membranes and the lower frequencies measure extraxcellular fluid (ECF). This gives an estimation of intracellular water and allows body

cell mass to be estimated for a more in depth analysis. Single frequency BIA (such as that used in the present study) has been studied extensively and has been shown to correlate well with isotopic dilution (Fearon *et al.,* 1992) and densitometry (Kushner and Schoeller, 1986). There are 3 main areas of error with BIA. The first concerns the method's assumption that the arms, legs and torso of the subject contribute equally to total body impendence when, in fact, the largest proportion of impendence is accounted for by the limbs (Kushner, 1992). If normal fluid balance exists then this assumption is valid, but if fluid distortion is present this method by give a wrong estimate of TBW depending on the location of the fluid (de Lorenzo *et al.*, 1991). Secondly whilst the technique is often described as being independent of observer error, unless electrodes are placed in exactly the same area each time a subject is measured, the reproducibility may be poor (Gartner *et al.*, 1992). The third area where error may be introduced is the BIA predication equations. As is the case with skinfold equations, the methods used for designing these equations in may make them population and age specific. This also applies to equations for predicating TBW from resistance (Garrow, 1983), which are validated in small groups.

Error is also introduced when TBW is used to predict FFM, since it is assumed that the hydration of FFM is constant (Garrow, 1983). Hydration fluctuates between individuals but is also a factor within subjects. Thus with children, equations that use FFM hydration of between 71.8% and 73.8% may overestimate FFM and underestimate fat (Lohman, 1988).

Norgan (1990) has criticised the use of BIA and suggests that skinfold thicknesses may be a more reproducible option. Lukaski however found that the error in calculated body fatness from skinfold thicknesses exceeded that from BIA.Since the late 1980s and early 1990s the use of this method in children and hence the validation of equations to predict FFM has grown (Cordain *et al.*, 1988, Davies *et al.*, 1988, Lohman *et al.,* 1989, Fjield *et al.,* 1990, Deurenberg *et al.*, 1990, Danford *et al.*, 1992, Wu *et al.*, 1993 Iwata *et al.*, 1993 and Houtkooper *et al.*, 1996). In this current study BIA was used to estimate TBW in 7-11

year old children. A predictive equation from Deurenberg *et al.*, (1991) was used which demonstrated a low standard error rate and high correlation coefficient in children aged 7-15, representative of the subjects in the study.

The relatively short time required to take the measurement and non-invasive nature of this method twined with the rising levels of obesity in children have generated an increase in the interest of using this method in children (Beertema *et al.*, 2000). Further work on prediction equations in children especially using greater sample sizes and cross-validation of the resulting equations will no doubt cement the evidence already suggesting its high validity in this group.

There is evidence to suggest that breakfast served at school affects diets quality, cognitive performance and behaviour in well nourished children and can effect growth in undernourished populations. It is the aim of the thesis to explore the hypothesis illustrated in figure 1.p and find out the difference between a breakfast served at school and eaten at home and the effects of the different types of breakfast on (1) diet quality (2) cognitive performance (3) behaviour (4) growth.

Aims of the Thesis

- To evaluate the effect of a breakfast club breakfast on breakfast quality, total day dietary intake and the contribution of different types of breakfast to daily intake.

- To investigate the effect of a breakfast club breakfast on cognitive performance and to examine the relationship between nutrient intake at breakfast and cognitive performance.

- To measure the effect of a breakfast club breakfast on growth and body composition and to seek out relationships between nutrient intake and growth and body composition.

- To examine the relationship between a breakfast club breakfast served at school and a breakfast eaten at home on child behaviour.

- To provide the evidence for the need for nutritional guidelines for the provision of breakfast at school

Chapter 2

Materials and Methods

In March 1999 the Director of Education at Falkirk Council Educational Services was contacted by Forth Valley Health Board Primary Care Development concerning opening breakfast clubs in the Falkirk area. Links were forged between Queen Margaret University College and Forth Valley Health Board and an evaluation study was discussed and proposed.

2.1 Recruitment of Subjects

Access to schools for the purpose of educational research was requested by Queen Margaret University College in March 1999 and was given by Falkrik Education Services. Ethical approval for the study was given by the Research Ethics Committee, Queen Margaret University College in April 2000. Once the author was in post 2 primary schools agreed to open breakfast clubs and subsequentially agreed to take part in the evaluation study. The 2 schools who agreed to act as Breakfast club schools were Cairmuirs Primary (school 1) and Slammanan Primary (school 2). The 2 schools were within 10 miles of one another and although the latter was a rural school the socio-demographic spread of the pupils were found to be very similar and the schools were of the same size. Six more primary schools were contacted with a view to them being recruited as control schools where breakfast would not be provided in school. Two schools agreed to act as control schools which were Avonbridge Primary (School 3) and California Primary (School 4) which were both small rural schools within a 2 mile radius of each other with the same catchment area. All children from ages 7-9 years old were invited to take part in the study which involved children from P3/4, P4/5, P5/6. This age group was chosen because there is relatively little information known about this particular group of children in respect to how what they eat at breakfast may affect their performance in the morning.

The Head teachers of the Breakfast club schools (schools 1 and 2) contacted parents in January 2000 about the opening of the breakfast club in order to gain some idea of how many children would attend. Research permission letters with tear off slips were handed out by teachers and were returned to completed in March 2000. The parents who replied positively to allowing their children to attend the breakfast club were then sent a second letter from the school, Falkirk Education services and the University College asking them if they would participate in a Forth Valley Health Board Study looking at what children eat and how they think. The letters were returned to the school via the form teacher. A second letter was sent out after 4 weeks to encourage more children to participate. Letters were then sent to children who did not plan to use the breakfast club but who would take part in the evaluation study as controls within the same school. Also it was expected that even though parents anticipated not sending their children to the club , once the club actually opened and the popularity of the club increased and there were peer pressure influences these same children might attend.

Since measurements were to be taken 4 times over the school year and it was a free living study where children could not be forced to stay in a particular group and anticipating drop out . A child attending the breakfast club in January (data collection 2) might not attend the club in March (data collection 3) and vice versa it would be beneficial to invite as many children as possible from the Breakfast Club schools to participate.

Letters were sent to children in the control schools after the breakfast club school had been recruited. Again letters were sent to parents asking for permission for their child to participate in a study looking at what children and how they think. Letters from each school differed slightly and were composed with the Head teacher to encourage co-operation from the parents.

Response Rate

Due to a low response rate the age group was widened from all children aged 7-9 years to all children aged 7-11 years old. Therefore all childreninr p6/7 were also included in the study. The selection criteria excluded any children suffering from chronic conditions which might affect dietary intake such as cystic fibrosis, diabetes mellitus or chronic renal failure (this amounted to zero). There was only 1 child from a different ethnic group than Caucasian.

Therefore all children in P3/4 and P5/6 and P6/7 were invited to take part in the study. These children were aged 7-11 years old. Collectively there were a total of 185 children took part in the study from the breakfast club schools namely Cairmuirs and Slammanan Primary and from the none breakfast schools. As illustrated in table 2.1a below there were 2 rounds of recruitment. Whilst 80 children aged 7-9 years old from the breakfast club schools were invited to take part in the study only 46 accepted. On the second round of recruitment 76 more children (aged 9-11 years old) from the breakfast club schools were asked to participate and only 14 children accepted. In total 60 children from the breakfast club schools agreed to take part in the study. The control schools were smaller in size than the breakfast club schools. During the first round of recruitment 55 children (aged 7-9 years old) from the control schools were asked to participate and 29 children accepted. At the second round of recruitment 52 children (aged 9-11 years) from the control schools were invited to participate in the study and 22 accepted. There were a number of reasons why parents did not want their children to participate. Many felt that the study may be too invasive. Collecting information about food intake is phenomenally difficult in adults and more so in children. Parents from socio-demographically challenged areas may feel that dietary information will reflect on their parenting skills. They may feel that a bad diet can be interpreted by more the socially advantaged researcher as sign that they are also a bad parent. Children who are overweight or obese are more likely to have overweight or obese parents who are less likely to allow their children's eating habits to be explored. The area

of Falkirk that was researched had a high percentage of unemployment and single parent families. For some of these parents feeding their children can be a struggle and food (or the lack of good quality food) may be an issue. The sensitive issues that surround eating are many and in this group of the population they may be more prominent. Parents were also informed that this research was looking at the effects that food might have on the way children think. This is also a highly sensitive issue and children and the parents of children who struggle academically or have areas of learning difficulty may not have wanted to take part in a study focusing on cognitive performance. Whilst every effort was taken to reassure parents that the research was endorsed by the head teacher the fact that the measurements would be made by a researcher from outside the school itself would no doubt have been a barrier to some families accepting to take part.

Table 2.1a : Response Rate of Study Participants

School	Cairmuirs		Slammanan		California		Avonbridge	
Age (years)	7-9	10-11	7-9	10-11	7-9	10-11	7-9	10-11
Ist Round Recruitment								
Invited	40		40		30		25	
Accepted	24		22		15		14	
2nd Round Recruitment								
Invited		39		37		28		24
Accepted		8		6		14		8
Total Response	32		28		29		22	

2.2 Subject Groups and Experimental Design

Baseline measurements were taken October – November 2000 before the commencement of the breakfast club . Breakfast clubs were opened in Cairmuirs and Slammanan Primary on the 20th and 14th of November 2000 (see table 2.1b below). Data was then collected sequentially in Cairmuirs Primary, Slammanan Primary, Avonbrige Primary and California Primary 3 more times over the school year 2000-2001. In the breakfast club schools, schools 1 and 2 data collection took 2 weeks to complete in each data collection time

period and in the control schools collection took a week each. There were 4-6 weeks between each collection period since collection had to be flexible around school holidays.

Table 2.2a The Data Collection Periods at Each School

	Baseline	Breakfast Club Start	Data Collection 2	Data Collection 3	Data Collection 4
Cairmuirs	23rd-27th October 2000	20th November 2001	22nd January - 5th February 2001	26t –30th March, 17th-20th April 2 001	14-28th May 2001
Slammanan	30th-13th November 2000	14th November 2001	9th-19th January 2001	5th- 15th March 2001	1-11thMay 2001
Avonbridge	13th -17th November 2000	N/A	20th-27th February 2001	17th–23rd April 2001	4th-8th June 2001
California	20th-24th November 2000	N/A	13th-20th February 2001	23rd-27th April 2001	11-15th June 2001

2.2.1 The Cross-Sectional Study (CS Study)

At baseline 111 children were eating breakfast at home or on the way to school. Whilst 60 children from the breakfast club schools consented to take part in the study_at data collection 2, 3 and 4 there were 23, 26 and 27 children who actually went to the breakfast club. These children formed the 'Breakfast Club' (BC) group. Children who did not go to the breakfast club but attended one of the breakfast club schools were classed as control group participants. The control group participants consisted therefore of children from the breakfast club schools who did not attend the breakfast club (i.e. they continued to eat breakfast at home despite the provision of a breakfast club at school) and children from the control schools where breakfast was not provided at school. This meant that there were 65, 68 ,72 children in the control group at each respective data collection point and these children were designated the 'Non-Breakfast Club' (NBC) group. Although it appears that there is only a small change of breakfast club attendants from each data collection point it must be highlighted that there are 13 'floating' subjects who have shifted from breakfast

club to non-breakfast club group or vice versa during the course of the last 3 data collection periods. The study was a free living study and so it was not possible to demand that children stayed in the breakfast club for the rest of the year after they had attended the breakfast club at data collection 2. The fluctuation of the subject numbers over the period of the study is depicted in figure 2.2a below.

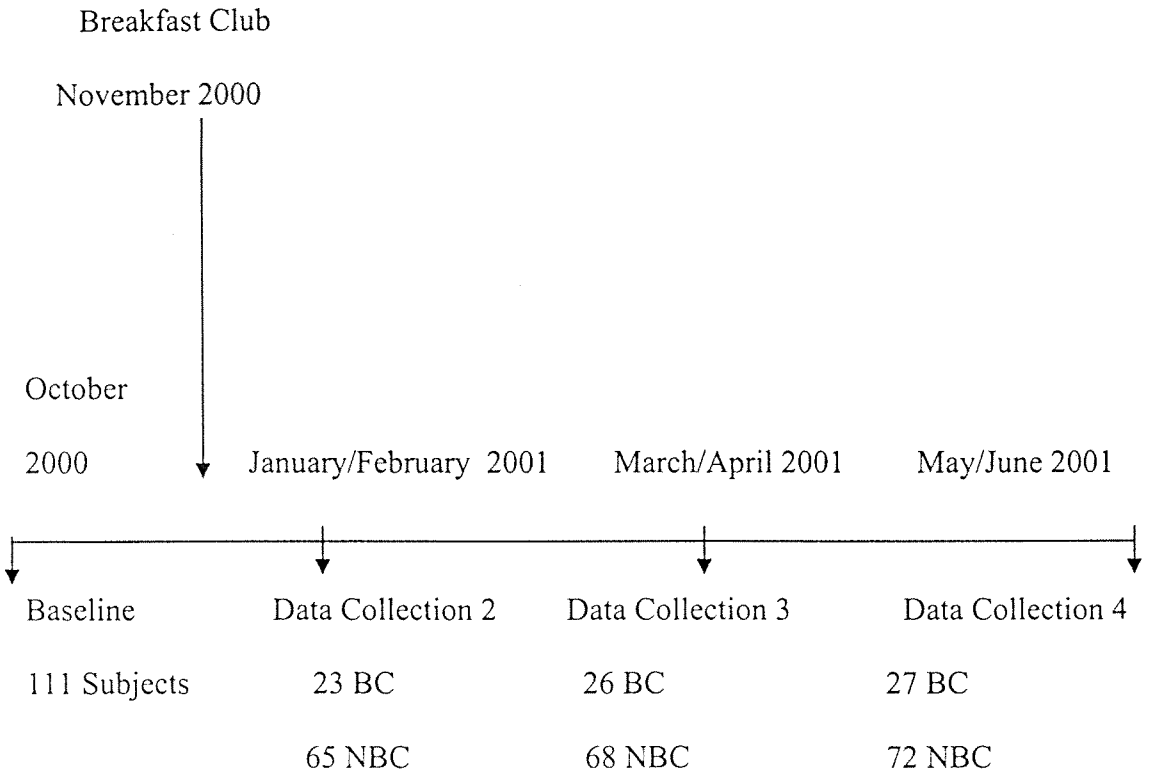


Figure 2.2.a Timeline and Fluctuation of Subject Numbers in the Cross-Sectional Study

The types of measurements that were taken at these data collection points are described in the following chapter (see 2.6 – 2.10). It should be noted here that all these measurements were taken for the children in the cross-sectional study (CS). However anthropometric measurements have not been analysed for this part of study. This is because nutrient intake is likely to affect growth in children over a period of at least 6 months, i.e. the children should stay in the same group from data collection 2 if the effects of the breakfast club on growth are to be sought. However the short-term intake of food may have an effect on cognitive performance and so only the breakfast eaten at that particular data collection period is relevant. Therefore CS analysis of the data was crucial for this.

The subject characteristics for pupils in the CS study have been described in tables 2. and 2.3 below. There were no statistical differences between the groups at any data collection periods. Due to missing data (due to breakfast club floaters) however each of the results chapter describes the subject characteristics for each of the measurements made.

Table.2.2b Number of Subjects in the BC and NBC Group for the Breakfast Meal Nutrient Analysis

	Baseline	Data Collection 2	Data Collection 3	Data Collection 4
BC	111	24	27	27
NBC		66	71	77

Table: 2.2c Subject Characteristics of the BC and NBC Group for the Breakfast Meal Nutrient Analysis

	BC	NBC
Baseline		
Age	9.7(± 0.09)	
Gender	58F:53M	
Data Collection 2		
Age	9.8(± 0.3)	10.1(± 0.2)
Gender	13F:11M	36F:30M
Data Collection 3		
Age	10.1(± 0.2)	10.2(± 0.1)
Gender	14F:13M	39F:32F
Data Collection 4		
Age	10.1(± 0.2)	10.2(± 0.1)
Gender	24F:6M	35F:26M

2.2.2 The Longitudinal Study (L.S Study)

Only 20 of the breakfast club children remained in the club for the entire study and these have been identified as the 'Breakfast Club 20' (BC20) group throughout the thesis. These 20 subjects have been age, sex and BMI matched with 20 subjects who did not attend the breakfast club for the whole of the research period. These children have been called the 'Non Breakfast Club 20' (NBC 20 group). These subjects have also been included in the C.S analysis and these subjects could only be elucidated after the end of the study once all

the data had been collected. The data collection periods are therefore exactly the same as for the C.S study and this is depicted in figure 2.4a below. The LS study was important for examining the effect of nutrient intake on body measurements. Children stayed in the same group throughout the study and so the longer term effects of dietary intake on anthropometry could be studied.

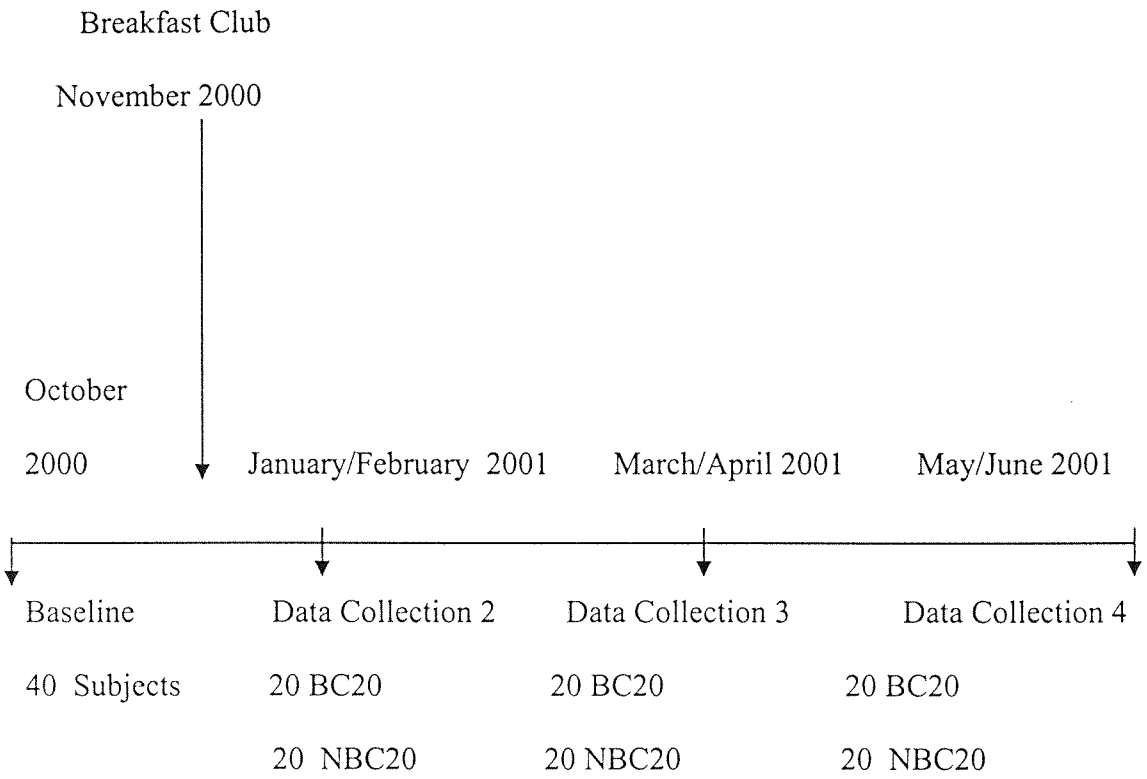


Figure 2.2b Timeline and Number Subjects in the Longitudinal Study

Subject characteristics of the LS study are described below in table 2.2d. These have also been described at the beginning of each of the results chapters because of the change in characteristics due to missing data.

Table: 2.2d Subject Characteristics for the Longitudinal Study

	BC20	NBC20
No. of Subjects at baseline	20	20
Gender (M:F)	10F:10M	10F:10M
Age at baseline	9.4(± 0.2)	9.8(± 0.2)
Height (cm)	136.1(± 1.5)	135.1(± 1.8)
Weight (kg)	32.1(± 1.4)	30.6(± 1.2)
BMI (kg/m^2)	17.6(± 0.8)	18.5(± 0.6)

2.3 Experimental Protocol

The following measurements were made at each of the 4 data collection periods:

1) Dietary Intake
2) Cognitive Performance
3) Anthropometric Measurements

At baseline and at data collection 4 child behaviour was also measured. Attitudes towards school for the teachers and children of the breakfast club schools only was examined by focus groups at the end of the study also.

Children filled in diet diaries for 3-days of each of the data collection periods. One of the mornings when the diet dairy was completed children were seen individually by the author for approximately 12 minutes in order to carry out cognitive function testing. A quiet room in the school was set aside for this for the duration of the study. Since the effects of breakfast only on cognitive function was one of the research aims pupils had to be tested before playtime before a 10.30am snack was consumed so that the effect of breakfast only was measured and not that of a mid-morning snack. This meant that there was only the short time window of 9.00am – 10.30am for children to be seen and a maximum of 8 children could be seen per morning depending on how long the tasks took each child. Diet dairies filled in by the pupils were also reviewed by the author at this point whilst children carried out the written coding test. On the Thursday and Friday afternoon of each test week between 12-00 and 3.30pm children were measured for height, weight, fat and fat free mass using BIA. Also during this time period the author was also able to interview each child with their food diary in order to estimate food portion sizes and to prompt forgotten foods as necessary. The methodology of each of these measurements is described in details below.

2.3.1 Measuring Dietary Intake

A child friendly 3- day estimated food diary was designed for the purposes of the study that was validated before the start of the study.

2.3.1.1 Comparative Study

In February 2000 access was gained to school 1 in order to pilot the estimated food diary and to gain knowledge of the ability of the children to estimate food portion sizes. 24 children were seen they were split evenly into the 7-9 and 9-11 year old age groups and were instructed on how to fill in a diary for the day before. The problem of easily forgetting the consumption of food from the day before was high lighted as well as the omission of snacks and drinks. The 2 age groups were further split into 2 groups for the food portion estimation exercise. One group worked with food models and the other group with the MAFF food portion photograph atlas. School portion sizes of food served at school lunch such as chips, peas, carrots, baked beans, pizza, spaghetti are standardised and portion sizes were known. These particular foods were chosen to be used as 'reference foods' for this exercise. The children were asked to recall the size of a school portion for e.g. chips and then depending on which group they had been placed in were asked to reconstruct the portion with plastic food models or point a photograph.

Independent t-tests were used to examine differences between actual school portion size and perceived photograph size and there were no significant differences ($p > 0.05$) were evident, i.e. the 50g of chips served at schools corresponded with the 50g in the MAFF food atlas. However differences were found for 3 of the foods (chips, peas and baked beans) in age group 7-9 and 2 of the foods on age group 10-11 (peas and baked beans) when children tried to estimate a food portion size using the food models ($p < 0.05$). Since amounts of breakfast cereal were of great interest in this study all four groups of children were asked to choose a cereal from Frosties, Cornflakes, Rice-Krispies, Co-co Pops, Cheerios and portion out into a bowl how much they would normally eat in the morning. Cereal portion sizes were 20–40g. Manufacturers standard portion sizes of cereal are 30g and in the MAFF food portion size atlas food photographs of cornflakes are shown in increments. A second portion size exercise was carried out where the 8 MAFF graduated photograph of cornflakes was replicated into real bowls of cereal, where the size and shape

of the bowls and amounts of cereal was an exact copy of that seen in the photographs. Each bowl was given a label in the form of a different coloured star for each portion size. The bowls were laid out in a random fashion and each child was asked to rearrange them in size order so that they replicated the order in the photographs. All of the children were able to reproduce the size order. It was decided therefore that the MAFF photographic atlas of food would be used to estimate portion size in this group of children. Whilst this exercise was a useful tool in comparing portion size estimation it was only a comparative study and could not be used as a direct method to validate the diet diaries.

2.3.1.2 The 3 -Day Estimated food diary

A child friendly 3-day estimated diary was constructed . Instructions were given orally to the child (with a practice run through of estimating food eaten from the day before) and in the written form with the aid of cartoon characters. The language was kept simple and the food used in the instructions and example diet were typical of a child's diet of that age. In the first 2 batches of diaries pull out plates were provided for the children to draw what they had eaten as well as pages to write down what they has consumed. Also a page was included to draw food and drink cartons. However older children found this inappropriate and tedious and as the study progressed the 'write and draw' technique was abandoned. It seemed to be only appropriate in children with borderline learning difficulties (n=5) or those at the lower end of academic achievement and once a rapport was made with these children it was possible to communicate well with them on a verbal level.

A few days before the commencement of the study each of the 4 schools was visited by the author in order to instruct them as to how to fill out the diet diary. Every child was given a diary and the instructions were read out to the children in form groups and any questions were answered. Each child was handed out a diary page to write down what they had eaten the day before. The children were then told which day they would have to start filling the dairy and were told to do this for 3 school days in a row and use a separate page for each day and to write the times they had eaten if possible. They were requested to write down

what they had eaten as soon as they had consumed the food. Pupils were reminded to fill in their diaries before lessons commenced, after playtime and lunch by either the form teacher of the researcher. Pupils were encouraged to take their diaries home to fill in the evening meals and snack bought on the way home form school. Although parents were not requested to help their was some parents participation in the filling in of diaries.

Since the author was available in school for most of the week (in order to carry out cognitive function testing and to carry out anthropometric measurements) she was able to inspect food diaries at intervals and prompt the children to complete the and to hand them back on the last day . At the end of the 3-day collection period the author was able to interview each child individually and go through the diary with them to estimate portion sizes with the MAFF food portion photographs. The children in the breakfast club were not requested to point out their breakfast food portion size because weights of the foods are known from the school caterer. Portion sizes at lunch are also known.

If a child consumed a 'hot' lunch at school a comparison was made between the food photographs and the actual food amount eaten, by independent t-tests. This was a useful method to clarify that the children were estimating the correct portion sizes from the photographs. All diaries were analysed by the author using the dietary analysis computer programme, Comp-eat 5.

2.3.1.3 Validating Energy Intakes

It is now widely accepted that mis-reporting is a major problem in dietary surveys, not just in adults, but also in children and adolescents (Livingstone *et al.*, 2000). The doubly-labelled water method which is considered to be the most accurate method of dietary assessment validation is too expensive and technically challenging to be used to validate estimated intake (EI) data. Indeed it would not have been possible to use this method in the present research due to its invasive nature. EI as a ratio of estimated or measured basal metabolic rate (BMR) can be used as the yardstick to examine the validity of EI. Physical activity level (PAL) is the ratio of overall dietary expenditure to BMR and is characterised

by a description of lifestyle. A PAL of 1.55 (based on the FAO/WHO/UNU; 1985) requirements for a sedentary lifestyle has been chosen as the yardstick to examine the validity of reported EI when expressed as EI:estimated or measured BMR. However whilst this single cut-off number has been used in studies validating dietary intake in children (Goldberg *et al.* (1991), one of it's major limitations is that it is of limited value for identifying under-reporting at the individual level.

Schofield equations for predicting basal metabolic rate from body weight in adults and children was reported in the Energy and Protein Requirements Joint FAO/WHO/UNU expert consultation (WHO, 1985). In the table below W represents weight in kilograms.

Table 2.3a: Equations for predicting basal metabolic rate from body weight

Age Range (years)	$Kcal_{th}$/day	Correlation Coefficient	SD
Males			
3-10	22.7 W + 495	0.86	62
10-18	17.5 W + 651	0.90	100
Females			
3-10	22.5 W + 499	0.85	63
10-18	12.2 W + 746	0.75	117

Estimated BMR was calculated by using the appropriate equation in the table for each age group and using the child's weight at baseline in kilograms. Values for CUT-OFFs differ according to the number of days that dietary intake was recorded (Goldberg *et al.*, 1991). Since the diaries assessed intake over 3 days the CUT-OFF value of 1.1 was used. Hence estimated BMR was multiplied by 1.1 to give a number which represented the minimum number of calories that a person of this age and weight could survive on. Therefore any estimated intake below this calculated number of calories is unlikely to be feasible and we can deduce that this person is likely to be under-reporting. Theoretical considerations

together with few existing cross-validation studies both suggest that under-reporting is much more prevalent than over-reporting (Goldberg *et al.,* 1991). Under-reporting was calculated by this method for the baseline collection only, since it is assumed that there will be the same degree of under-reporting at the 3 other data collection periods. The percentage of under-reporters in each is shown at the beginning of the results section.

2.3.2 Measuring Cognitive Performance

A large number of mental or cognitive tasks are potentially able to demonstrate the effects of foods on performance. In practice however, a limited number of tests have been used. Some of the more frequently used ones are shown over the page (see table 2.3b).

Table 2.3b The Type of Functions assessed by cognitive tests

Function	Example of Tests	Common component of task
Vigilance (also known as sustained attention), rapid information processing, or continous performance	Search tests, e.g. categoric search, Digit symbol substitution (Coding), Stroop	Detection of stimulus items from particular categories The subject must replace Digits with symbols Subject must attend to certain features of stimuli and ignore others
Visual information processing Reaction time (decision and movement time)	Critical flicker fusion threshold Simple or choice	Subject must detect flicker and fusion of light Stimulus appears (visual or auditory) and subject must make a single response, usually by depressing a key; in the choice reaction-time test, one of a number of stimuli make appear and the subject must make one of two responses (e.g. left or right hand)
Frontal executive	Immediate recall e.g Digit Span	Subject is shown a list of stimuli at a given rate (e.g., one per second); at the end of the presentation the subject must recall the stimuli
Working memory (short-term memory)	Verbal memory Spatial memory Associative memory Word recognition Pattern comparison	 Subjects must recognize rather than recall the stimuli Subjects must descriminate or recognize patterns
Immediate memory	Digit Span	Subject must remember (recall) series of items in forward or reverse order
Reasoning	Arithmetic, logical, grammatical, or semantic	Subject must process and indicate whether stimulus is true or false
Psychomotor performance	Pursuit rotor	Subjects must trace a shape (maze) with a stylus under time pressure; error score is computed
Visuospatial motor task	Simulator or driving task Tapping task	 Subject must tap in rapid succession to a key

Many studies have administered "off-the-shelf" tests in a test battery. In the selection of tests careful consideration of the cognitive and neuropsychological faculties that the tests measure and the specific functions they unravel need to be taken into consideration (Dye *et al.*, 2000). One of the most widely used battery of tests is the Wechsler Intelligence Scale which is available for both adults and children. The coding, fluency, arithmetic and

digit (backwards and forwards) subtest of the scale was used in Simeon and McGregor's studies which looked at breakfast and cognitive performance in undernourished children in Jamaica (1989 and 1995). Benton and Parker have also used subtests of this scale in their laboratory based experiments which looked at university students and the effect of no breakfast or a glucose drink on cognitive performance (1992). Also subtests of the earlier versions of the score (WISC-III, WISC-R) as well as the WISC-III^{UK} have been used in several studies looking at nutrient intake and performance (Bellisle *et al.,* 1998).

In order to investigate 3 different areas of cognitive performance which may affect school learning 3 different of cognitive performance were considered. The areas of immediate memory, sustained attention and Arithmetic were chosen because of the previous use of these tests in breakfast studies (as listed above) and were recommended and approved by a paediatric clinical psychologist and chosen in conjunction with the supervising psychologist for this research. The (WISC-III^{UK}) is an individually administered clinical instrument for assessing the individually administered clinical instrument for assessing the intellectual ability of children aged from 6 years through to 16 years, 11 months and it measures different facets of intelligence and cognitive performance. The scale is described below.

Organisation of the Scale

The WISC-III^{UK} comprises 13 subsets. Tables 2.3c and 2.4d lists the WISC-III^{UK} subtests, provides a brief description of each and the function assessed.

Table 2.3c Descriptions of the Verbal WISC- III^{UK} subtests

Subtest	Description	Specific Abilities
Verbal		
Information	A series of orally presented questions tap the child's knowledge about common events, objects, places and people.	Range of general factual knowledge
Similarities	A series of orally presented pairs of words for which then child explains the similarity of the everyday objects or concepts they represent.	Logical abstractive (categorical thinking)
Arithmetic	A series of arithmetic problems which the child solves mentally and responds to orally.	Computational skill
Vocabulary	A series of words presented orally which the child defines	Language development Word knowledge
Comprehension	A series of orally presented questions that require the child to solve everyday problems or to show understanding of social rules and concepts.	Demonstration of practical information Evaluation and use of past experience Knowledge of conventional standards of behaviour
Digit Span	A series of orally presented number sequences which the child repeats verbatim for Digits Forward and in reverse order for Digits Backward.	Immediate auditory memory

Table: 2.3d Descriptions of the Performance WISC- III^{UK} subtests

Performance		
Picture Completion	A set of colourful pictures of common objects and scenes each of which is missing an important part which the child identifies.	Visual recognition identification (long-term visual memory)
Coding	A series of simple shapes (Coding A) or numbers (Coding B) each paired with a simple symbol. The child draws the symbol in its corresponding shape (Coding A) or under its corresponding number (Coding B)	Sustained attention and psychomotor speed
Picture Arrangement	A set of colourful pictures, presented in mixed-up order, which the child rearranges into a logical story sequence.	Anticipation of consequences Temporal sequencing and time concepts
Block Design	A set of modelled or printed two-dimensional geometric patterns which the child replicates using two-colour cubes	Analysis of whole into component parts Nonverbal concept formation
Object Assembly	A set of jig-saw puzzles, each presented in a standardized configuration, which the child assembles to form a meaningful whole.	Ability to benefit from sensory-motor feedback
Symbol Search	A series of paired groups of symbols, each pair consisting of a target group and a search group. The child scans the two groups and indicates whether or not a target symbol appears in the search group.	Speed of visual search
Mazes	A set of increasingly difficult mazes.	

The WISC-III[UK] subtests are then grouped into either the verbal or performance scales

Table: 2.3e The Verbal and Performance Subsets of the WISC-III [UK]

Verbal	Performance
2 Information	1 Picture Completion
4 Similarities	3 Coding
6 Arithmetic	5 Picture Arrangement
8 Vocabulary	7 Block Design
10 Comprehension	9 Object Assembly
12 Digit Span	11 Symbol Search
	13 Mazes

In addition to the Verbal and Performance and Full Scale IQs, 4 factor-based index scores can be calculated: (1) Verbal Comprehension (VCI) (2) Perceptual Organisation (POI) (3) Freedom from Distractibility (FDI) and (4) Processing Speed (PSI).

Table: 2.3f Scales derived from factor analyses of WISC-III[UK] subtests

Factor I	Factor II	Factor III	Factor IV
Information	Picture Completion	Arithmetic	Coding
Similarities	Picture Arrangement	Digit Span	Symbol Search
Vocabulary	Block Design		
Comprehension	Object Assembly		

The digit span test and arithmetic subtest combined give a Freedom from Distractibility (FDI) score.

Test Administration

The tests were administered to the children in the order of coding, digit span and arithmetic. Testing started at 9.00am every morning and each child was seen individually by the researcher. The coding score was a written test where each child was given 2 minutes to code digits into symbols. Next the digit span test was administered which was involved the researcher vocalising a string of numbers to the child which the child repeated back to the investigator in a forwards and backwards sequence. The researcher was able to score children on the score form whilst administering the test. The string of numbers increased in size and the child was asked to repeat these back to the researcher in forwards and backwards order until they made a mistake. At this point the digit span test

was stopped. The arithmetic test was administered aurally by the researcher who scored correct answers on a score form and finished and stopped at the first incorrect answer.

Time of Testing From Breakfast Consumption

The time of testing for each child was recorded at the baseline measurement. The order of testing was repeated at data collections 2,3 and 4 to try and ensure as much as possible that each child was tested at the same time at each data collection point. The exact time when breakfast was eaten was recorded by the subjects and the exact time of testing was recorded by the researcher. The average time between the time lag between consumption of breakfast and cognitive test performance is recorded below. The time between breakfast consumption and cognitive performance testing was between 30 minutes – 180 minutes. Children who ate breakfast at the breakfast club would be tested 30 minutes –180 minutes after breakfast consumption, whereas children eating breakfast at home were tested 60 -180 minutes after breakfast consumption. There was a significant difference in the time between when the children in the BC group from the BC schools were tested and between the NBC group from the BC schools and NBC schools ($p>0.05$).

Table: 2.3g Time Lag Between Breakfast Consumption and Testing

	BC Group	NBC Group
	Time (in mins)	
BC Schools	60	100
NBC Schools		110

Statistical Analysis

The original WISC was designed in the US in 1949 and although it retains essential features of earlier editions, the WISC- III^{uk} provides updated test materials, test content and administration procedures, and current normative reference points based on a UK validation programme. The WISC-III^{uk} norm tables were based on the scores of children

used in a UK validation study which was used to establish a set of UK normative reference points. Hence subtests scores were entered onto record forms and these scores were changed into scaled subtest scores using the conversion "norm tables" in the manual. Scales scores are based on the child's age and each table provided scaled scores for a four-month age span. Independent t-tests were used to explore the differences between the breakfast club and non-breakfast club groups. No differences were found and so differences between the baseline scores and scores at data collection 2 , 3 and 4 were explored using paired t-tests. Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS, Version 10.0).

2.3.3 Anthropometric Measurements

Height

A portable Child Growth Foundation stadiometer (Minimetre) measuring 180cm in 0.1 cm increments was used to measure height. The stadiometer was placed against an upright wall and standing height was taken without shoes with the child's heels and back in contact with the wall. The child's head was held so that he or she looked straight forward with the lower borders of the eye sockets in the same horizontal plane as the external auditory meati (i.e. head not with nose tipped upwards). The arm of the stadiometer was brought down until the bottom surface touched the child's head and the scale was read and recorded to the last 0.1cm. During the measurements the child was asked to stretch their neck to be as tall as possible , although care was taken to prevent the child's heels from coming off the ground. The child was gently stretched upwards by being held under the mastoids.

Weight

Weight was measured on a set of Soenle floor scales weighing to 127kg in 0.1kg increments. Shoes and heavy clothing were removed and weight was measured to the nearest 0.1kg after asking the child to stand motionless on the scales with feet together. The accuracy of the scales was assessed by measuring a set of standard weights in 0.5kg increments to 55kg.

Bioelectrical Impendence Analysis (BIA) – measuring fat and fat free mass

In recent years bioelectrical impedance analysis (BIA) has been suggested as a quick and reliable method of investigating body composition. It is reported to be precise, non-invasive (Smith 1993) and not observer-dependent (Richardson et al 1990) and is relatively inexpensive (Kushner et al, 1990).

Bioelectrical impedence analysis (BIA) relies on the properties of electrical conductivity and makes the assumption that the body is made up of electrical conductors, capacitors and resistors (Kushner, 1992). Lean tissue is highly conductive to an electrical current since it has a high water and electrolyte content, whereas adipose tissue is more resistant.

In this study, the single frequency BIA-101A bioelectrical impedance plethysmograph (RJL Systems Ltd, Michigan, USA) measuring resistance to 1000ohms in 1ohm increments was used to estimate total body water on each subject at the 4 data collection time periods. Bioelectrical impedance analysers operate with frequencies which alternate between a positive and negative charge, between 2 electrodes. The impedance of the tissue is calculates by measuring the voltage between these 2 electrodes.

The child was placed in the supine position, with their arms positioned at the side 30° from the body, the palms flat and prone, and the legs kept straight apart to avoid inconsistencies in the impedance measurement. One pair of pre-gelled electrodes was placed between the styloid processes of the radius and ulna of the right wrist and between the tibial and fibular malleoli of the right foot. A second set was placed on the right hand and foot just proximal to the heads of the third metacarpal and metatarsal bones respectively. Electrical leads

were attached to the electrodes using crocodile clips and resistance was measured by passing a constant current of 800 mcA at a single frequency of 50kHz between the electrodes. All children were instructed to empty their bladder immediately prior to the measurement..

The single frequency BIA-101A used in the study was tested for accuracy, according to the manufacturers' instructions. The BIA was fully charged prior to the test and was disconnected from the mains power supply. A 500 Ohm resisitor (RJL Systems Ltd, Michigan,USA) was attached to the subject cables, with the 2 red clips adjacent to the cylinder of he test resistor, and the cables separated to either side of the test resistor. The power was switched on and the resistance value was recorded. The resistance level displayed between 490 and 501 ohms showed the impendence circuitry and battery were within acceptable limits. Cable connectors were checked by pressing lightly o the base of the cables where they were attached to the BIA system, for any fluctuation in the resistance (more than several ohms) and the cables were also moved to different positions to check for breaks in the cables.

The accuracy of prediction equations for estimating human body composition is dependent in part on the accuracy of measurement of the criterion variable. (Houtkooper et al 1996). Very few equations have been developed to predict fat-free mass FFM in children from whole bioelectrical impedance measurements alone or from impedance combined with anthropometric variables. (Houtkooper et al 1992).

Fat free mass was calculated using the equation shown below (Deurenberg, 1991). Deurenberg looked at body composition at an age range of 7-83 years and measured it by densitometry, anthropometrics and biometrical impudence. The relationship between densitometrically determined fat free mass (FFM) with body impedance(R), body weight (W) and body height (H) was analysed, taking age and sex into account the intercept of the regression equation $FFM= a \times H^2/R+ b$ was found to be age , and at (older ages) sex dependent, increasing from age 7 to 15, and slowly decreasing after age 16.

The best fitted prediction formula at ages <- 15 was:

$FFM = 0.406 \times 10^4 \times H^2/R = 0/360\ W + 5.58\ H + 0.56\ Sex - 6.48$

Where

FFM = fat free mass

W = body weight in kg

H = body height in metres

Sex (male = 1, female = 0)

From this measure of fat free mass, fat mass can be ascertained from total body weight

Fat mass = total body weight – fat free mass

2.4 Child Behaviour

The Achenbach teacher report form (Acehbach, 1991) was used to measure child behaviour. This is 118-item behaviour rating scale identifies problems in 19 key areas: academic performance (reading, writing, maths), working hard, behaving appropriately, learning, happiness, adaptive functioning, withdrawn behaviour, somatic complaints, somatic score, anxiousness/depression, internalising behaviour, social problems, thought problems, attention problems, inattention, hyperactivity-inpulsitivity, delinquent behaviour, aggressive behaviour, externalising behaviour and other problems . These scores can be funnelled into 4 main headlines - anxiety, social withdrawal, self – destructiveness, nervousness and aggression. However due to time restraints and with the knowledge that the scale is too long, the questions too abstract or the rating of each behaviour item too limited (dichotomous), the teachers may hesitate to participate (Edelbrock, 1983), the checklist was reduced in size. Therefore the 19 key area have been examined separately in the thesis since it was not possible to amalgamate them into the 4 factors.

2.5 Statistical Analysis

Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS, Version 10.0). To compare difference between the group independent t-test were used to reveal any significant differences between the groups. Intra-group comparisons were also performed where appropriate using the paired t-test. Repeated measures ANOVA tests were used for intra-group comparisons of the cognitive performance scores for the L.S study only. Correlative analysis was performed to indicate associations between results. Results were checked for normality of distribution. If normally distributed a Pearson correlation was used and, if results were not normally distributed, a Spearman correlations was used. Linear regression was used to look at relationships between variables. Results with a value of $p<0.05$ were considered significant. Descriptive data has been expressed as mean ± standard error of the mean (SEM) in the thesis.

3.1 The Breakfast Meal

Breakfast is defined as any food or drink consumed prior to the first morning lesson at school. At baseline (October- November) all children were eating breakfast at home or on the way to school. Breakfast clubs were opened in 2 of the 4 schools at the end of November 2000. At the second data collection point in January-February 2001 there were 22 children in the breakfast club (the BC group) and 66 children in the non-breakfast club group (the NBC group). At data collection 3 in March-April 2001 there were 27 in the BC group and 71 in the NBC group. In May-June 2001, the fourth data collection point there were 27 children in the BC group and 77 in the NBC group. The variation in group numbers is represented in table 3.1a and the subject characteristics are illustrated in table 3.1b below. The results illustrated are the mean values of nutrient intake from breakfast over the 3–days of data collection at baseline and each of the 3 subsequent data collection periods.

The purpose of this chapter is to:

examine the differences between breakfast intake of the BC 20 and NBC 20 group at baseline and data collection 2,3 and 4 (using independent t-tests), and to examine the % RNI provided by the breakfast meal.

Subject Numbers and Characteristics

Subject characteristics have been described in chapter 2 . However due the fluctuation in the number of children in the BC and NBC at each data collection period is also described below.

Table 3.1a Number of Subjects in the BC and NBC Group for the Breakfast Meal Nutrient Analysis

	Baseline	Data Collection 2	Data Collection 3	Data Collection 4
BC	111	24	27	27
NBC		66	71	77

Table: 3.1b Subject Characteristics of the BC and NBC Group for the Breakfast Meal Nutrient Analysis

	BC	NBC
Baseline		
Age	9.7(± 0.09)	
Gender	58F:53M	
Data Collection 2		
Age	9.8(± 0.3)	10.1(± 0.2)
Gender	13F:11M	36F:30M
Data Collection 3		
Age	10.1(± 0.2)	10.2(± 0.1)
Gender	14F:13M	39F:32F
Data Collection 4		
Age	10.1(± 0.2)	10.2(± 0.1)
Gender	24F:6M	35F:26M

3.1.1 Baseline – October/November 2000

The greatest variety of foods for this meal was consumed at the baseline measurement before the commencement of the breakfast club. This breakfast was eaten at home and in some cases was supplemented on the way to school. Figure 3.1a refers to the types of breakfasts consumed by each subject over the 3 days of baseline measurement. At the baseline measurement over 50 % of the children were eating (RTEBC) only over the 3-day of measurements whilst 6% were eating a cooked breakfast only and 14% were eating a cooked and cereal breakfast over the course of the 3-days.

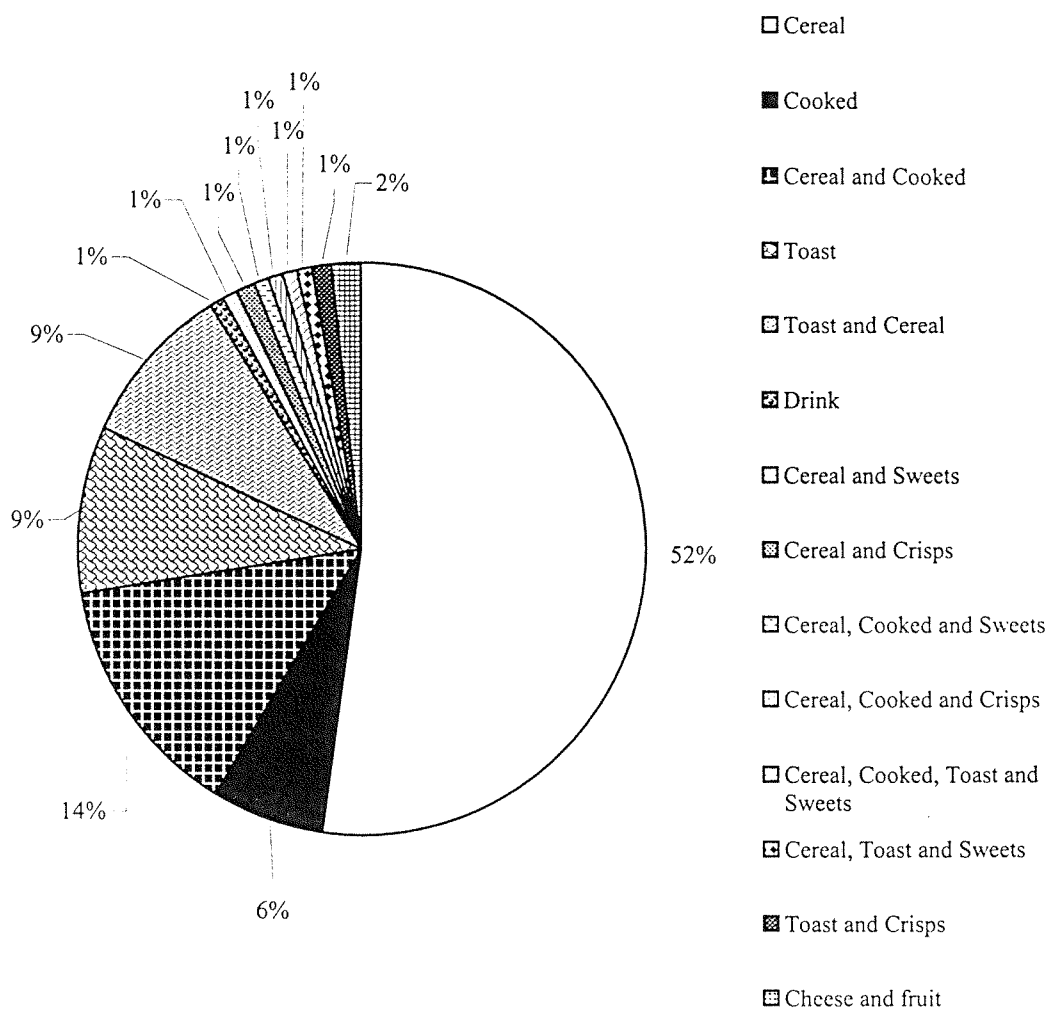


Figure 3.1a Types of Breakfast Consumed at Baseline

Energy and Nutrient Intake at Baseline Breakfast

As illustrated in figure 3.1b below at baseline 61.1% of the energy from breakfast was from carbohydrate. Approximately equal amounts of this energy were attributed to energy from starch (32.1%) and sugar (29.9%). Fat contributed to 25% of the energy for breakfast at baseline.

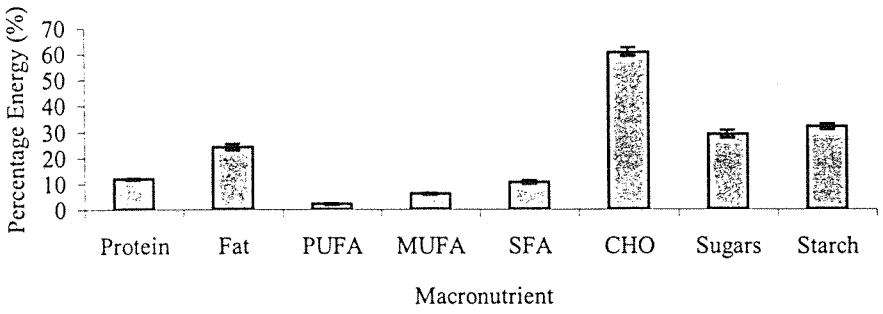


Figure 3.1b Percentage Energy of Macronutrients at Baseline Breakfast

Where PUFA= polyunsaturated fatty acids

MUFA= monounsaturated fatty acids

SFA=saturated fatty acids

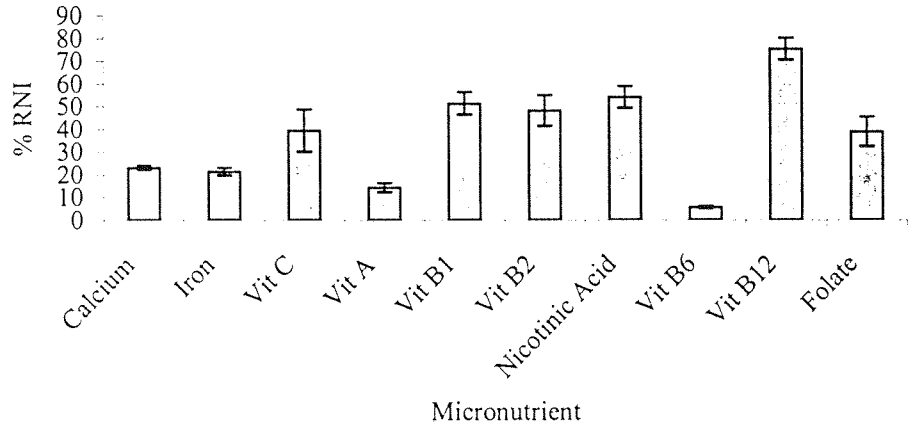


Figure: 3.1 c % RNI Micronutrient Provided By Breakfast at Baseline.

Under Reporters

Estimated intakes were compared to BMR as described in chapter 2.3 and the percentage of children under-reporting could be calculated using a CUT-OFF point. At baseline we can assume that 96% of the children were reporting their dietary intakes accurately. There was an average estimated intake of 664.7 (± 302) kcal more than the BMR.

Overview of How the Breakfast Club has Affected Nutrient Intake At Breakfast Over The School Year.

Since only 20 subjects from the breakfast club group attended the breakfast club throughout data collection periods 2,3 and 4 the subjects in BC group of each data collection period are changing. Therefore each period cannot be compared directly to each other. However the differences in nutrient composition between the BC and NBC breakfast for each data collection period have been presented together below. This is so that an overview of how the breakfast club has affected the children over the year can be seen. As shown in figure 3.1d there were significantly greater numbers of cereal consumers in the non-breakfast club group.

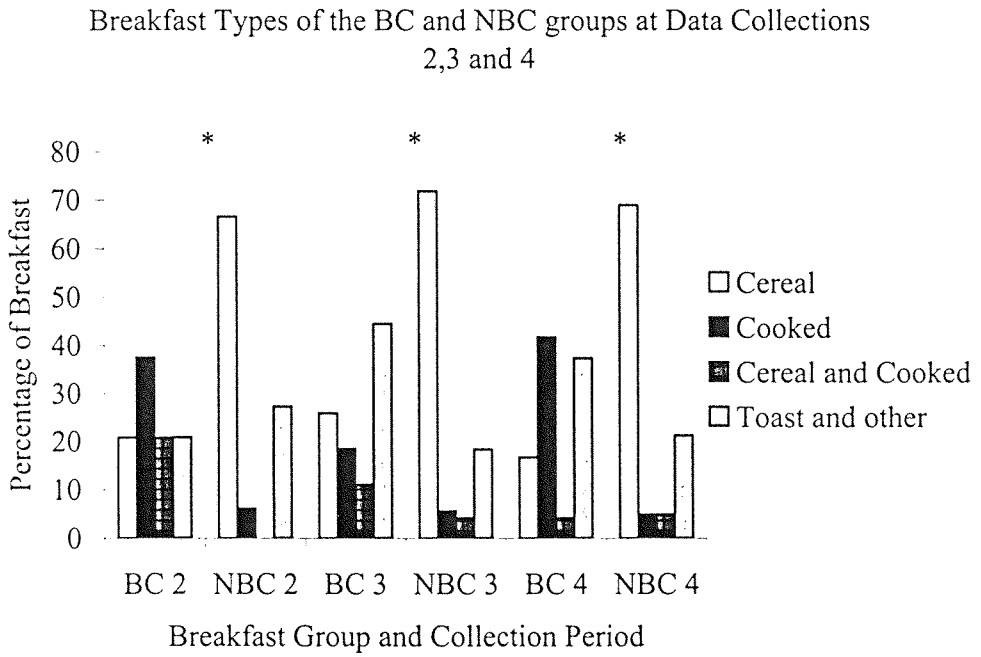


Figure: 3.1d Breakfast Types of the BC and NBC groups at Data Collections 2, 3 and 4 where $^{*}p \leq 0.05$, , $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$.

3.1.2 Differences in Breakfast Intake During Data Collections 2, 3 and 4 Between the BC and NBC Groups

Macronutrient Differences Between the Breakfast Meals of the BC and NBC Groups

In all 3 data collection periods there was a significantly greater amount of calories consumed by the BC group the breakfast meal than the BC group (as illustrated in figure 3.1e below).

Figure 3.1e Calories from the Breakfast Meal of the BC and NBC Group

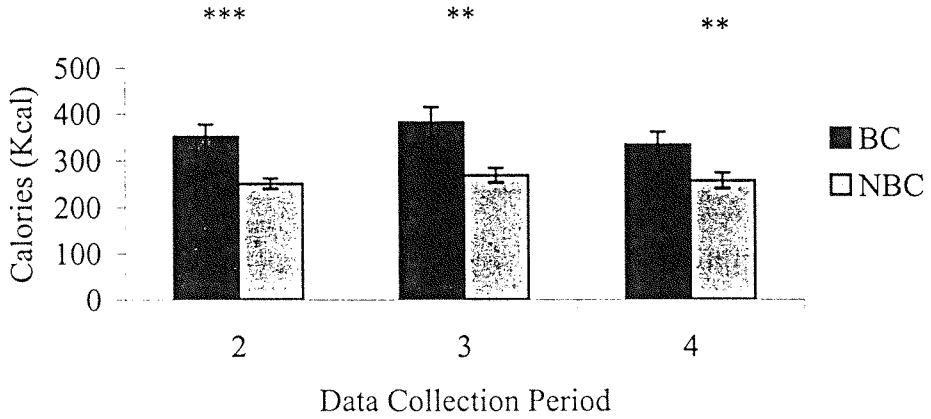


Figure: 3.1e Calories from the Breakfast Meal of the BC and NBC Group
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$.

CHO intake at breakfast was also greater for the BC group at all data collection periods but the difference in CHO intake between the groups was only significant at data collections 2 and 3 (as depicted in figure: 3.1f below)

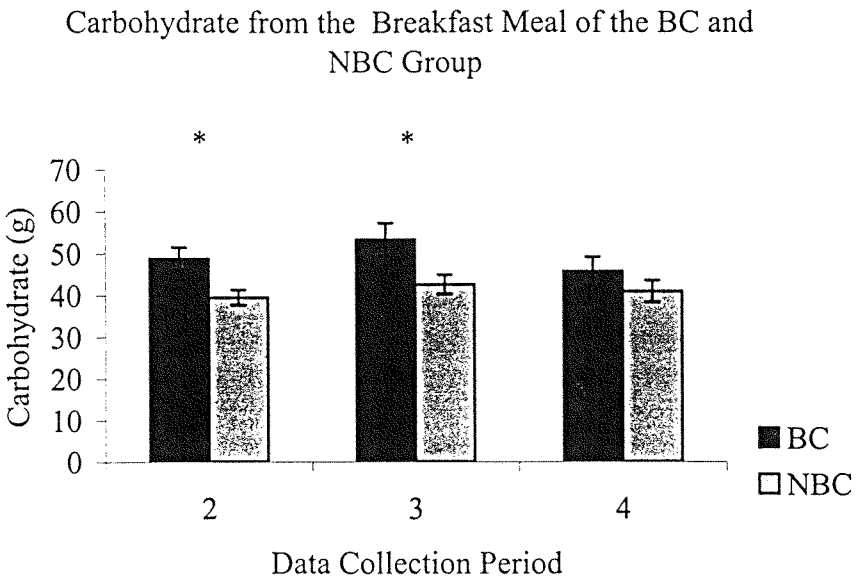


Figure:3.1f Carbohydrate from the Breakfast Meal of the BC and NBC Group
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

As illustrated in figure: 3.1g and 3.1h the higher carbohydrate intake at breakfast was due to a higher intake of both starch and sugars by the BC group at all 3 data collection points. The difference in starch intakes at breakfast was significant at data collection 2. Sugar intake was significantly greater at data collection 3 for the BC group and close to significance at data collection 2.

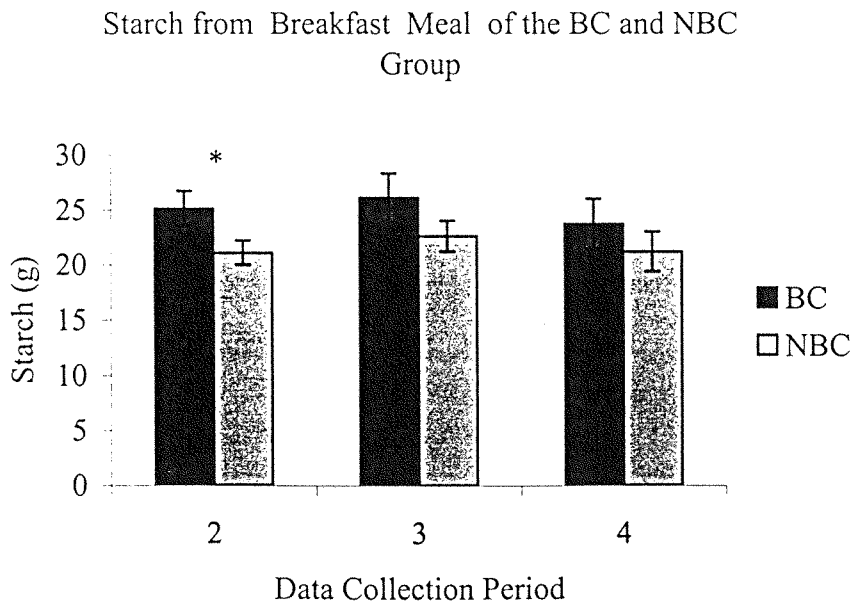


Figure: 3.1g Starch from Breakfast Meal of the BC and NBC Group
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

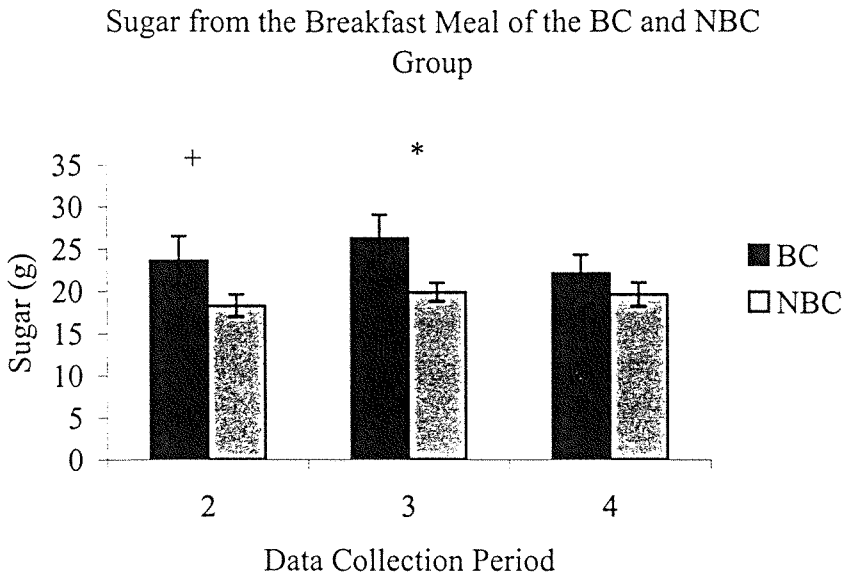


Figure: 3.1 h Sugar from the Breakfast Meal of the BC and NBC Group
where $^{+}$=0.05-0.06, $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

As illustrated in figure:3.1i below greater amounts of protein was present in the breakfast meal of the BC group at all 3 data collection periods. There was a significant difference in protein intakes between the BC and NBC groups at data collections 2 and 3. .

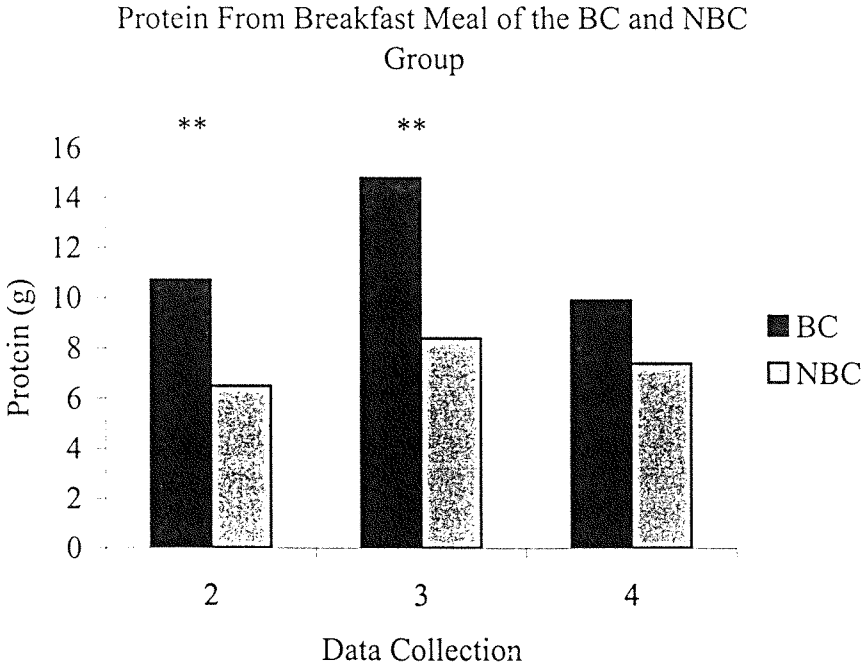


Figure: 3.1i Protein From Breakfast Meal of the BC and NBC Group
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

Fat consumption from the breakfast meal was greater for the BC group at data collection 2, 3 and 4. Referring to figure: 3.1j below the difference in fat intake was significant at data collection 2. As illustrated in figures 3.1k-3.1o the difference in fat intake was because of a significantly higher intake of PUFA and MUFA in the BC group. The BC groups were eating a significantly greater amount of cooked breakfast which constituted of a hot filled roll with 10g of sunflower spread or olive spread, and so higher intakes of MUFA and PUFA were to be expected. Figure 3.1l depicts the difference in the % RNI PUFA from the breakfast meal. Breakfast should provide 20% of nutrient intake and so the BC group were above this recommendation at each data collection point.

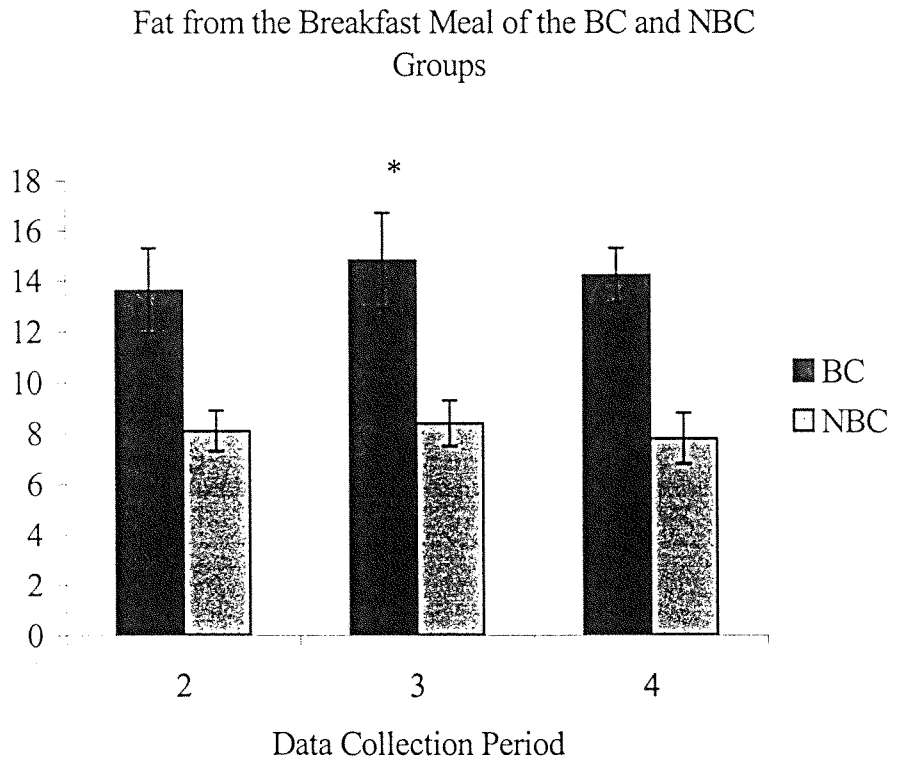


Figure 3.1j Fat from the Breakfast Meal of the BC and NBC Groups
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

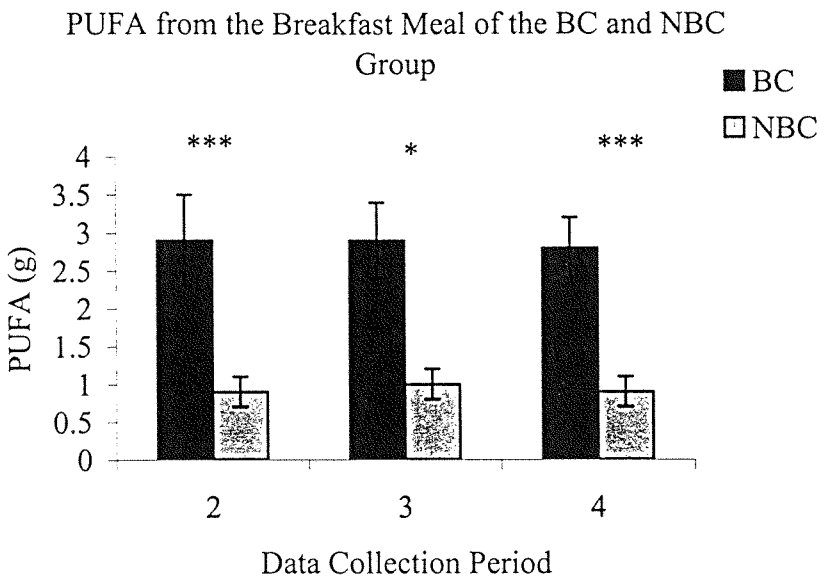


Figure: 3.1k PUFA from the Breakfast Meal of the BC and NBC Group
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

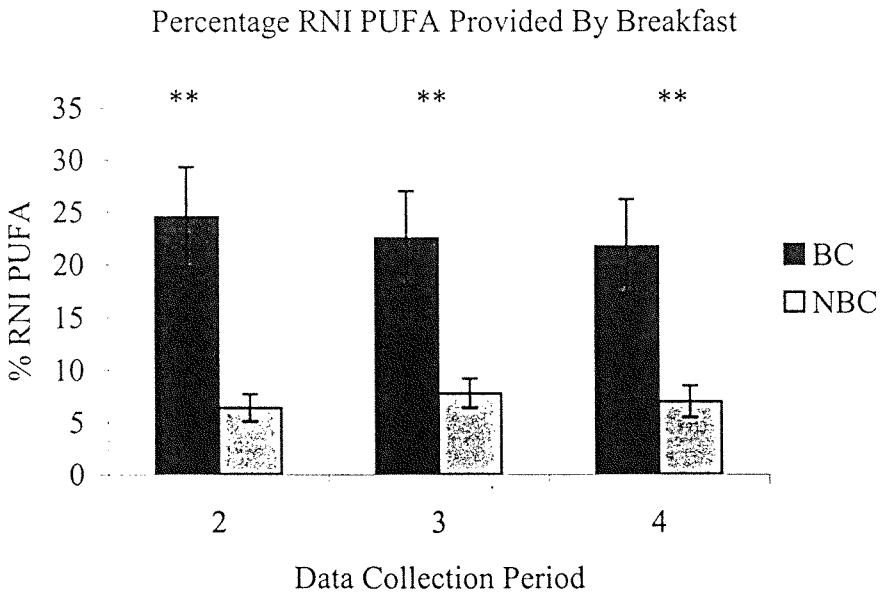


Figure: 3.1l Percentage RNI PUFA Provided By Breakfast
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

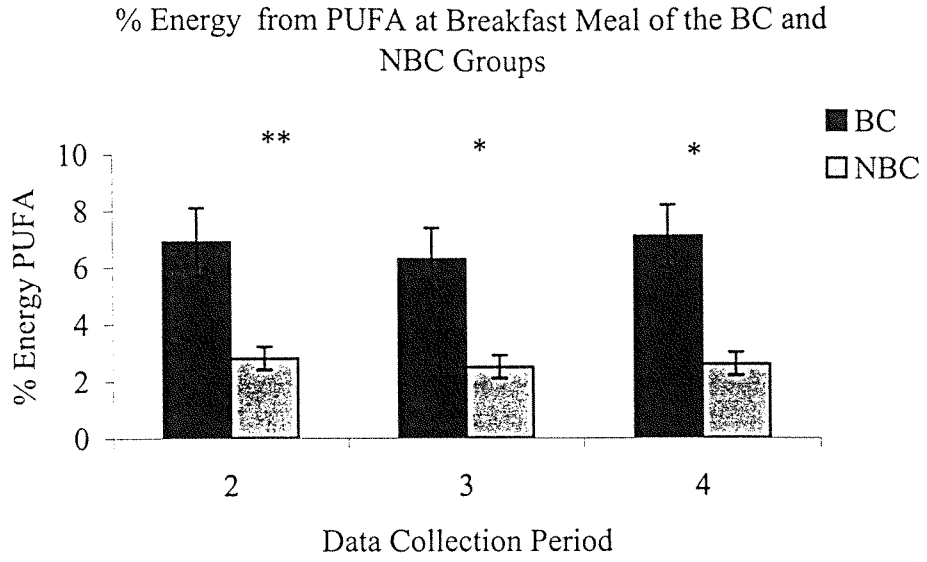


Figure: 3.1m % Energy from PUFA at Breakfast Meal of the BC and NBC Groups where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

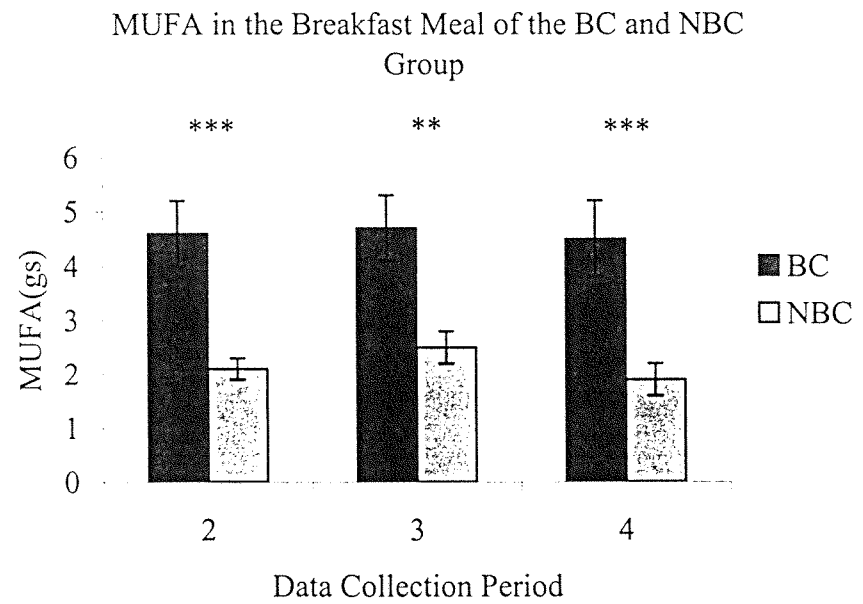


Figure:3.1n MUFA in the Breakfast Meal of the BC and NBC Group where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

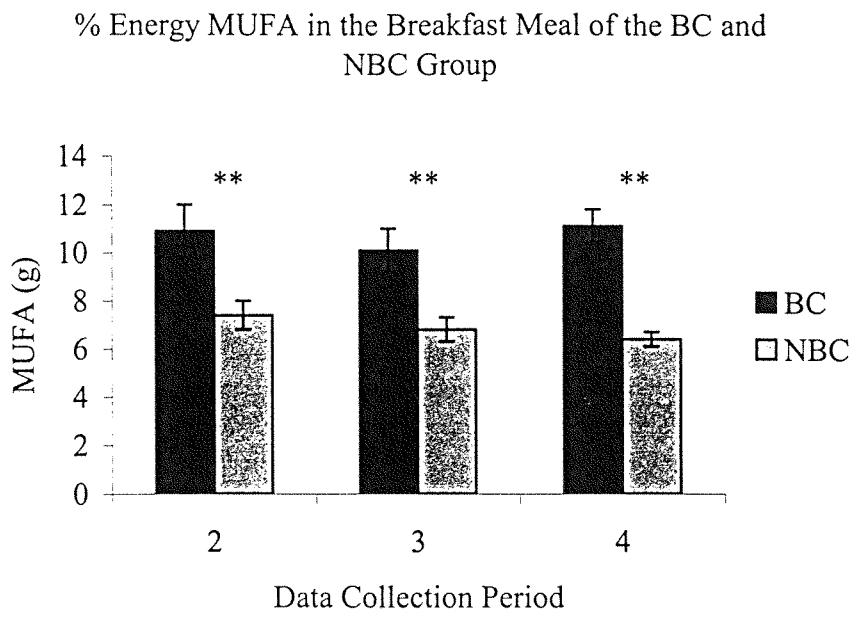


Figure: 3.1o % Energy MUFA in the Breakfast Meal of the BC and NBC Group
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

Micronutrient Differences Between the Breakfast Meals of the BC and NBC Groups

At data collections 2 and 3 the breakfast meal eaten by the BC group provided a significantly greater amount of Ca ($p \leq 0.05$ as shown the graph below).

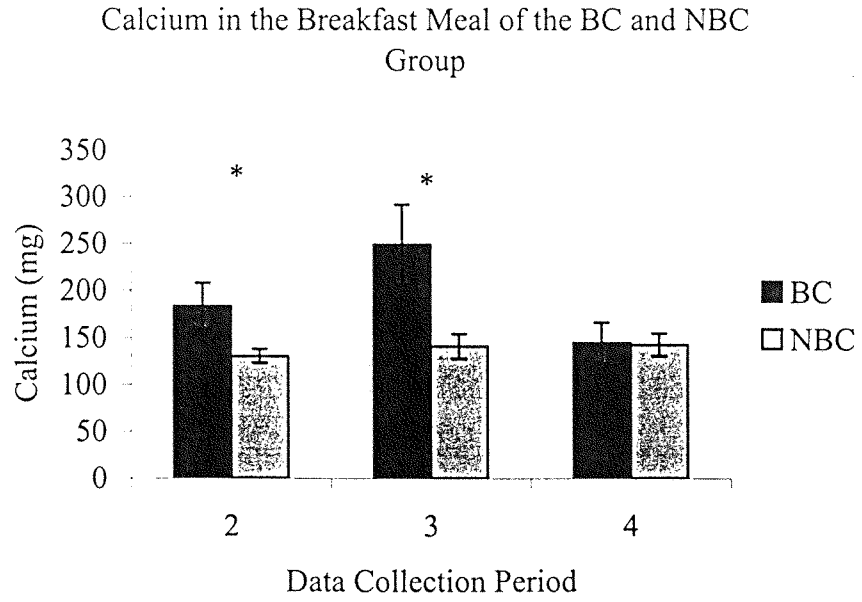


Figure: 3.1p Calcium in the Breakfast Meal of the BC and NBC Group
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

Vitamin A intake at breakfast was also higher for the BC group at all 3 data collection periods (see figure 3.1q below).

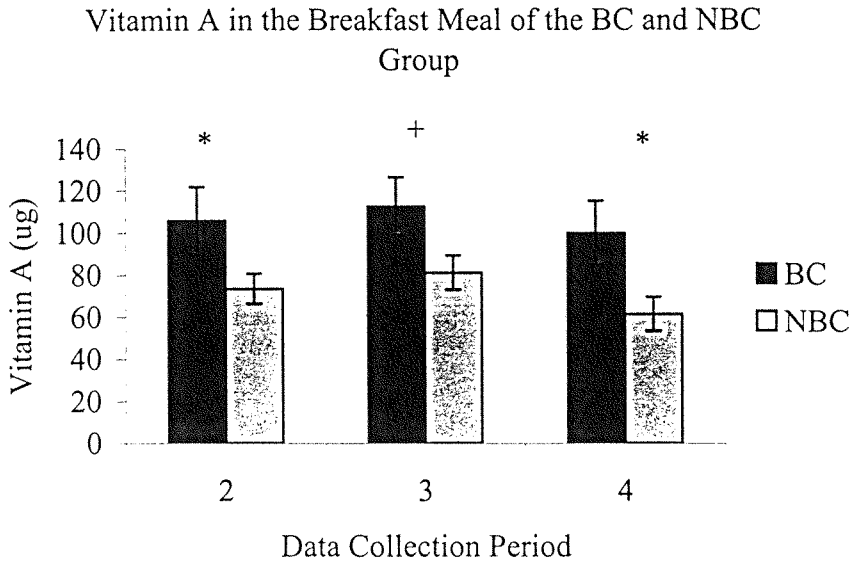


Figure: 3.1q Vitamin A in the Breakfast Meal of the BC and NBC Group
where $^{+}$=0.05-0.06, $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

The BC breakfast also contained greater amounts of vit C and the difference between the groups was significant at data collection 3, as illustrated in figure: 3.1r.

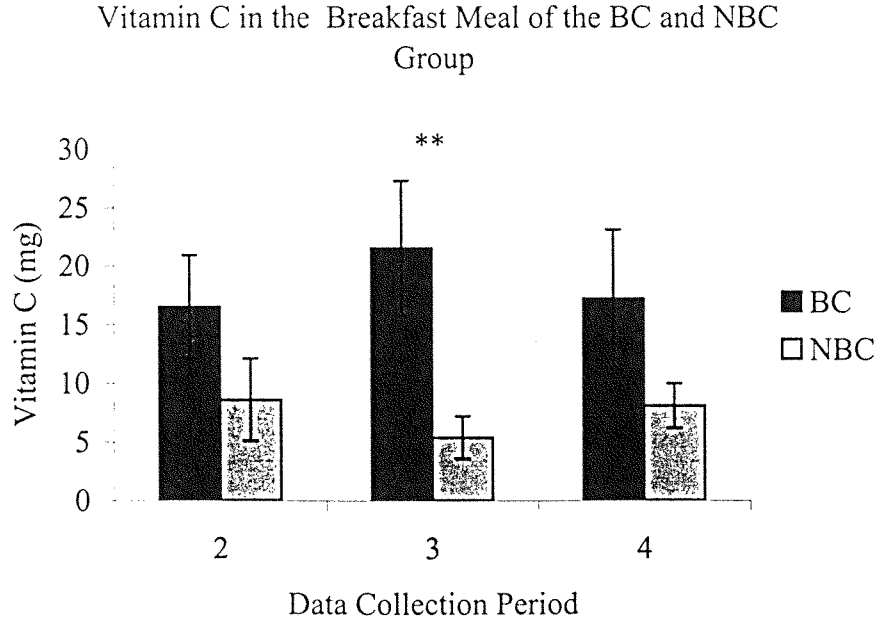


Figure: 3.1r Vitamin C in the Breakfast Meal of the BC and NBC Group
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.00$

The higher intakes of vit C in the breakfast of the BC group meant that this group were achieving a higher % RNI for this vitamin. The BC group were getting a significantly higher percentage RNI of vit C from the breakfast meal at data collection 2. At data collections 3 and 4 they consumed more than 50% of the RNI for vit C at the breakfast meal. The NBC group were achieving group were achieving a higher % of the RNI for B2 ($^{+}$ =0.05-0.06) and a significantly greater amount of % RNI BI ($p \leq 0.01$) at data collection 4 .

3.1.3 Discussion

The breakfast of the BC group provided a greater amount of calories. CHO intake *per se* was higher in the BC group at all 3 data collection periods. The percentage energy from CHO whilst not significant is higher for the NBC group at all 3 time periods. Starch and sugar intakes are also greater *per se* for the BC group and the % energy of both starch and sugar were greater in the breakfasts of the NBC group. At each of these time periods there was a significantly higher percentage of RTEBC only eaters. RTEBC are high in carbohydrate and so this will have an effect on the % energy from CHO at the breakfast meal. Ruxton's research into the diets of Edinburgh school children looked at the difference in energy and nutrient intakes at breakfast by weekly frequency of ready-to-eat breakfast cereals (RTEBC) (Ruxton *et al.,* 1996). The groups were divided into children who ate RTEBC 6-7 times a week, 4-5 times a week and 0-3 times a week. Children who ate RTEBC 6-7 times a week got 68% of their energy from CHO, whilst moderate RTEBC eaters had a breakfast that consisted of 62% energy from CHO, whilst the low RTEBC eater had only 30.4% of energy from CHO. At data collection 2 more than 50% of the NBC group were eating RTEBC only over the 3 days of the study and % energy from CHO was 61.2% (versus 54.4 for the BC group). More than 50% of children in the NBC group at data collection 4 were eating only RTEBC for breakfast and % energy from CHO was 55.9(versus 54.4 in the BC group). At the last data collection point 60% of

children in the NBC group ate cereal only for breakfast and % energy from CHO for this meal was 61.1 as compared to 54.4 in the BC group.

Protein intakes were higher for the BC group at all data collection points 2, 3 and 4. At all these time periods there were significantly greater numbers of children eating a cooked breakfast. The cooked breakfast included sausage, bacon, egg and cheese filled rolls whose protein content would increase overall protein intakes at breakfast. However there was no difference in % energy protein at breakfast between the 2 breakfast groups.

At data collections 2, 3 and 4 the BC breakfast contained greater amounts of fat, due to the use of 10g of sunflower or olive spread in the hot filled rolls consumed by the BC group. This meant that this group were consuming greater amounts of PUFA and MUFA at the breakfast meal. There were significantly higher amounts of cereal eaters at all 3 data collection points in the NBC group and since breakfast cereals tend to be low fat this difference in fat intake is expected.

In Ruxton's study the higher the frequency of RTEBC consumption the lower the % energy from fat at the breakfast meal. The findings of the present study reflect this also. Whilst many studies have looked at the mean daily intake of energy and nutrients according to consumption of breakfast cereals, very few have investigated the nutrient difference in different types of the breakfast meal alone. One exception is Greer in his study of 1-5 year old children who found that energy and fat intakes were lower at the breakfast meal children eating cereal than those who ate other types of breakfast (Greer, 1990). A recent study by Cho showed that breakfast cereal eaters had lower fat intakes and higher vitamin intakes than those eating pastries or ham and eggs for breakfast (Cho *et al.*, 2003). Different types of breakfast were also investigated by Preziosi and cereal consumption was associated with a greater proportion of daily energy from CHO and a lower proportion of energy from fat (Preziozi *et al.*, 1999). The effect that breakfast types have total daily intake and the contribution of breakfast to total daily intakes will be discussed further in chapters 3.3 to 3.4.

Calcium intakes were higher for the BC group than the NBC group at data collections 2 and 3. Whilst there were greater numbers of RTEBC consumers at these data collection periods in the NBC and a $1/3^{rd}$ of all milk is consumed with breakfast cereal (NDNS, 2000), the presence of milk or milkshakes as a drink at the breakfast club increased the consumption of Ca at this meal. Vit A intakes were higher in the BC group and this was probably due to the higher milk consumption an fortification of the margarine used in the hot filled rolls. Vit C intakes were higher in the BC group due to fresh orange juice being available at the breakfast club.

There were a higher percentage of cereal eaters in the NBC group at all data collection points. Since breakfast cereals are fortified to at least 25% RNI for the B-vitamins at data collection 4 the NBC group were achieving a higher % of the RNI for B2 ($^{+}$=0.05-0.06) and a significantly greater amount of % RNI BI ($p \leq 0.01$). Many studies have shown improved daily micronutrient profiles especially for the B-vitamins because of the consumption of breakfast cereals (i.e. Ortega *et al.*, 1995, Kafatos *et al.*, 2003, Gibson *et al.*, 2003).

3.2 The Change in Breakfast Intake from Baseline

The change in nutritional composition of the breakfast meal consumed at baseline and that consumed at data collection 2, 3 and 4 by the BC and NBC group has been explored in this chapter. This has been calculated by subtracting the breakfast at baseline nutritional values from the breakfast at data collection 2,3 and 4, i.e.

difference in nutritional composition of breakfast = nutrient value of breakfast at data collection 2,3 or 4 minus nutrient value for breakfast eaten at baseline

The purpose of this chapter therefore is to explore the changes in macro and micronutrient intake from the baseline breakfasts to the breakfast eaten at data collection 2 ,3 and 4 and to examine the differences between the BC and NBC groups.

Subject Numbers and Characteristics

Subject characteristics have been described below (Chapter 2.3). However due to fluctuation in the number of children at baseline the difference in calories from baseline to data collections 2 ,3 and 4 are different from those in chapter 3.1

Table 3.2a Number of Subjects in the BC and NBC Group for the change in nutrient intake at Breakfast Meal form Baseline

	Baseline to Data 2	Baseline to Data 3	Baseline to Data 4
BC	23	25	21
NBC	64	69	60

Table: 3.2b Subject Characteristics of the BC 20 and NBC 20 Group for the Breakfast Meal Nutrient Analysis

	BC	NBC
	Baseline to Data 2	
Age	9.8(± 0.4)	10.1(± 0.5)
Gender	11F:12M	35F:29M
	Baseline to Data 3	
Age	10.1(± 0.7)	10.2(± 0.3)
Gender	13F:12M	40F:20M
	Baseline to Data 4	
Age	10.1(± 0.4)	10.3(± 0.4)
Gender	9F:12M	36F:24M

3.2.1 Change in Breakfast Intake from the Breakfast at Baseline for the BC and NBC Groups at Data Collections 2,3 and 4

Changes in Macronutrient Intake from Baseline

As illustrated in figure:3.2a there were increases in the amount of calories from the breakfast consumed at baseline for the BC and NBC groups. However the increases in calories for the BC group now consuming a breakfast at school was significantly greater at data collections 2 and 4 than the increase in calories for the NBC group.

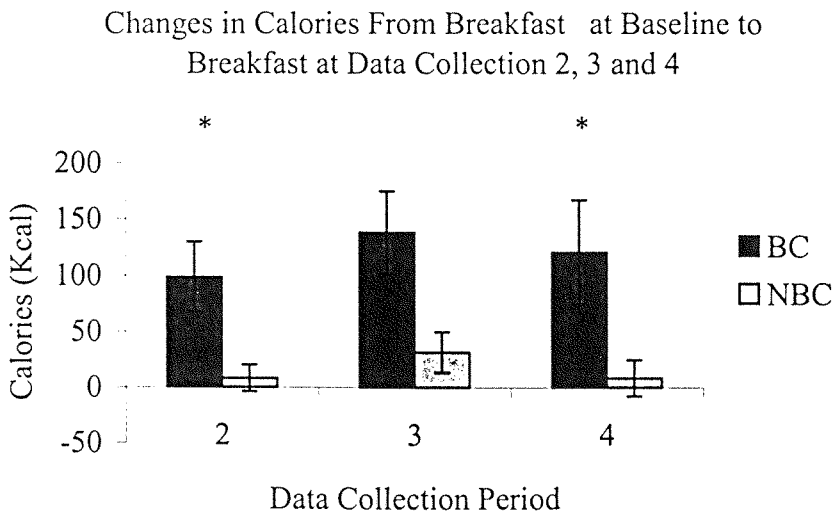


Figure: 3.2a Changes in Calories From Breakfast at Baseline to Breakfast at Data Collection 2, 3 and 4
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

Whilst increases in CHO were greater for the BC group, there was also an increase in CHO from the breakfast at baseline to the breakfast at data collections 2,3 and 4 and the differences between the groups were not significant (see figure 3.2b below). As illustrated in figures 3.2c and 3.2d below this was due to an increase in both starch and sugars for both groups.

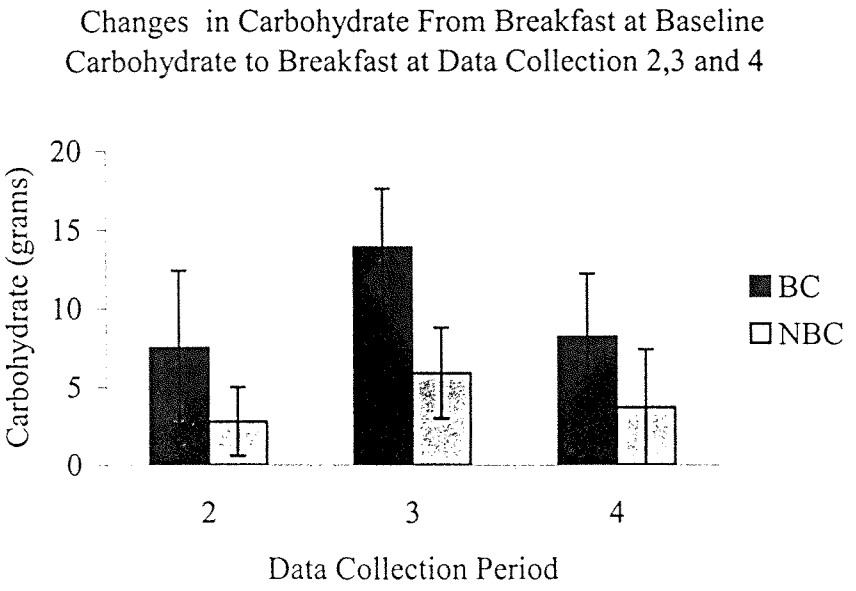


Figure: 3.2b Changes in Carbohydrate From Breakfast at Baseline Carbohydrate to Breakfast at Data Collection 2,3 and 4
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

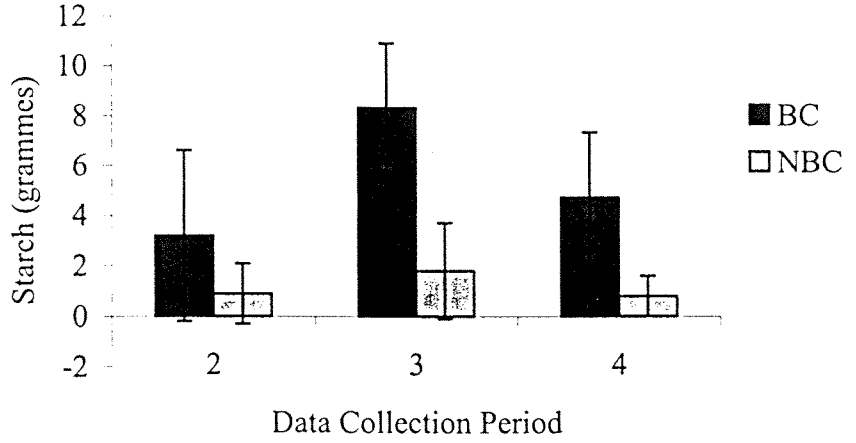


Figure: 3.2c Changes in Starch From Breakfast at Baseline Minus Starch to Breakfast at Data Collection 2, 3 and 4
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

Figure: 3.2d Changes in Sugar From Breakfast at Baseline Minus to Breakfast at Data Collection 2, 3 and 4.

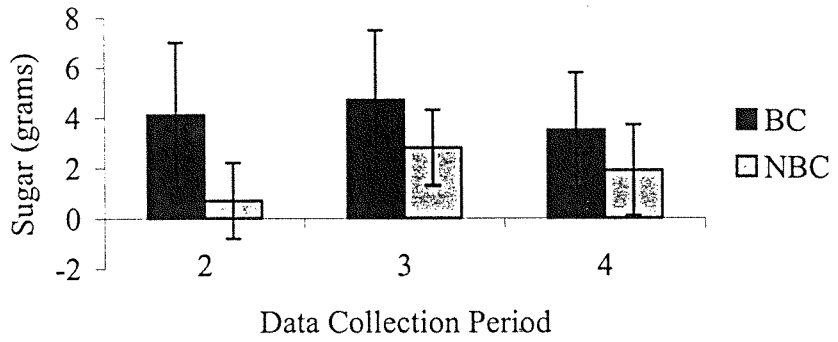


Figure: 3.2d Changes in Sugar From Breakfast at Baseline Minus to Breakfast at Data Collection 2, 3 and 4.
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

Figure:3.2e depicts the changes in % energy from fat from breakfast at baseline. Whilst there were increases of more than 5 % energy from fat for the BC group at all time periods, there were only small increase for the NBC group and a reduction in % energy from fat at data collection 3.

Changes In Percentage From Energy Fat From Breakfast at baseline to Breakfast at data Collection 2,3 and 4

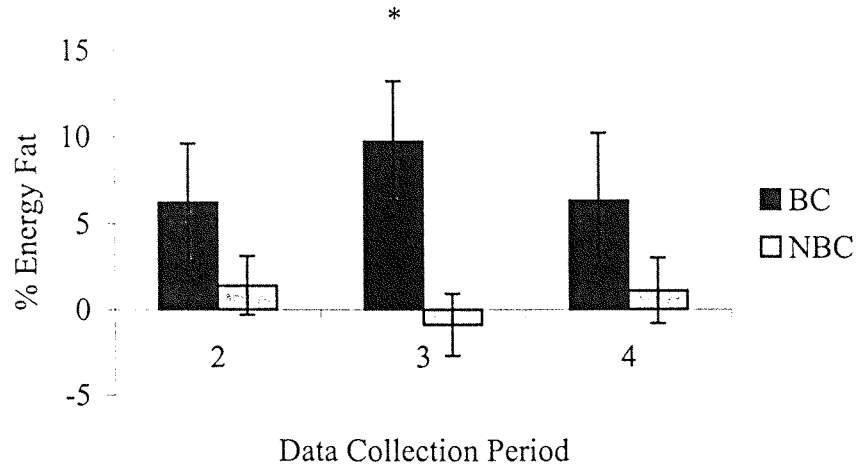


Figure: 3.2e Changes In Percentage From Energy Fat From Breakfast at baseline to Breakfast at data Collection 2,3 and 4
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

There were significant increases in the amounts of PUFA and MUFA from breakfast at baseline for the BC group as compared to the NBC group (as shown in figure 3.2f and figure 3.2g).

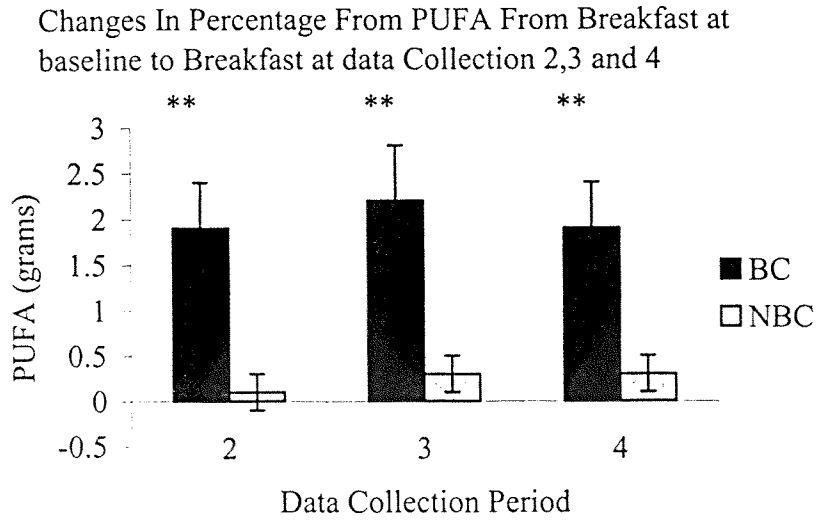


Figure: 3.2f Changes In Percentage From PUFA From Breakfast at baseline to Breakfast at data Collection 2,3 and 4
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

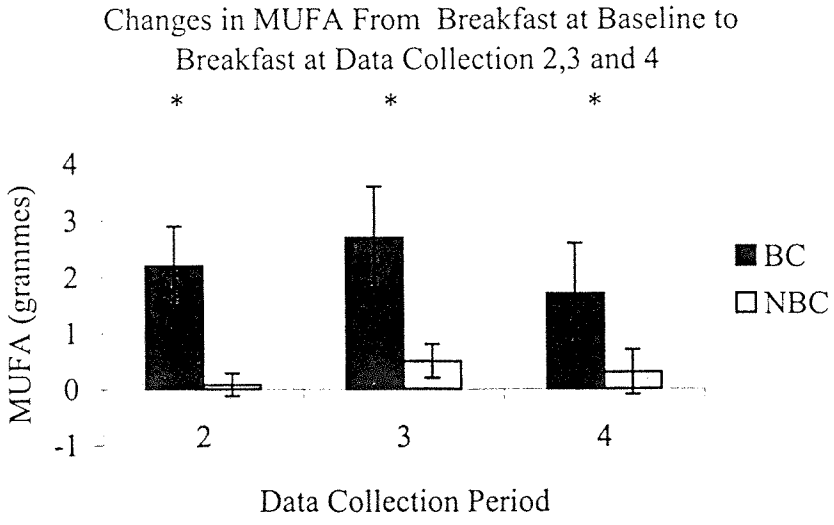


Figure: 3.2g Changes in MUFA From Breakfast at Baseline to Breakfast at Data Collection 2,3 and 4
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

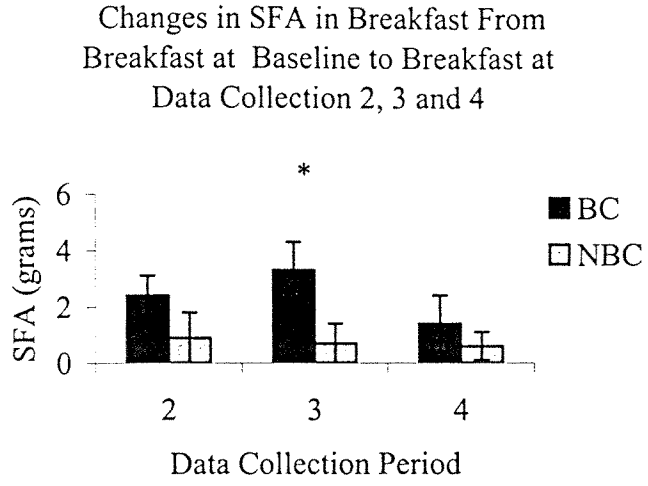


Figure: 3.2h Changes in SFA in Breakfast From Breakfast at Baseline to Breakfast at Data Collection 2, 3 and 4
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

Figure 3.2h above shows that whilst there were increases in SFA for both groups since the breakfast at baseline the increase was greater for the BC group and significantly so at data collection 3.

Changes in Micronutrient Intake from Baseline

There were increases in the amount of Ca consumed at breakfast as data collections 2,3 and 4 when compared to the breakfast eaten at baseline for the BC group at data collection 2 and 3 as represented in figure: 3.2i below.

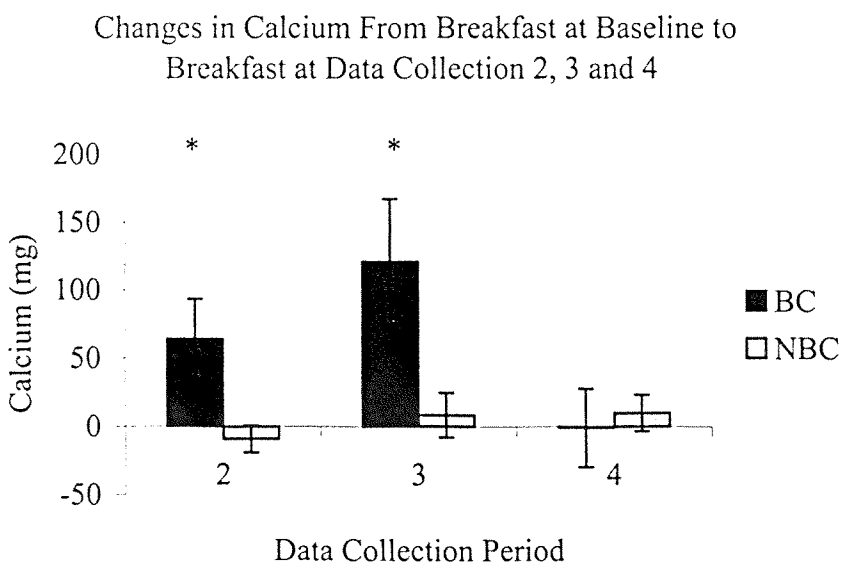


Figure: 3.2i Changes in Calcium From Breakfast at Baseline to Breakfast at Data Collection 2, 3 and 4
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

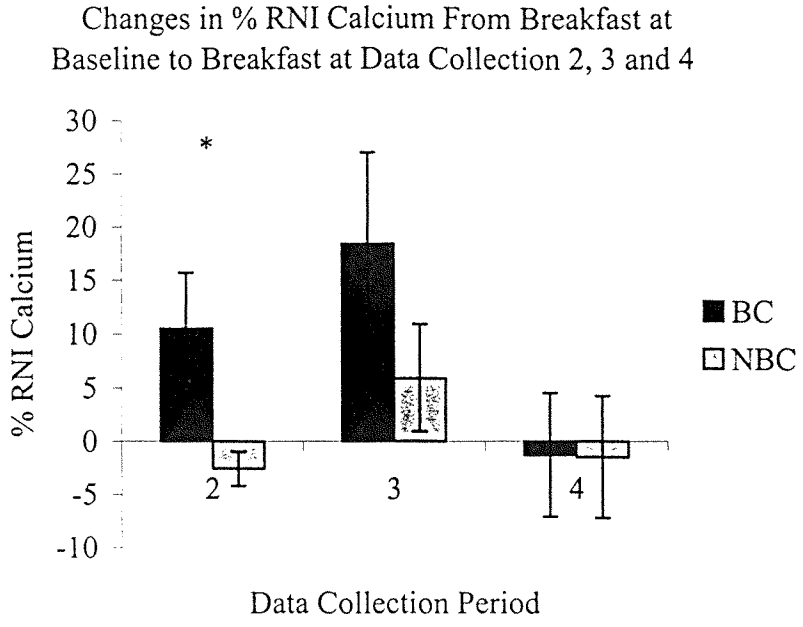


Figure: 3.2j Changes in % RNI Calcium From Breakfast at Baseline to Breakfast at Data Collection 2, 3 and 4

where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

Whilst there were increases in vit C intake at all 3 data collection periods for the BC group group there were decreases for the NBC group (although this difference between the groups was not significant).

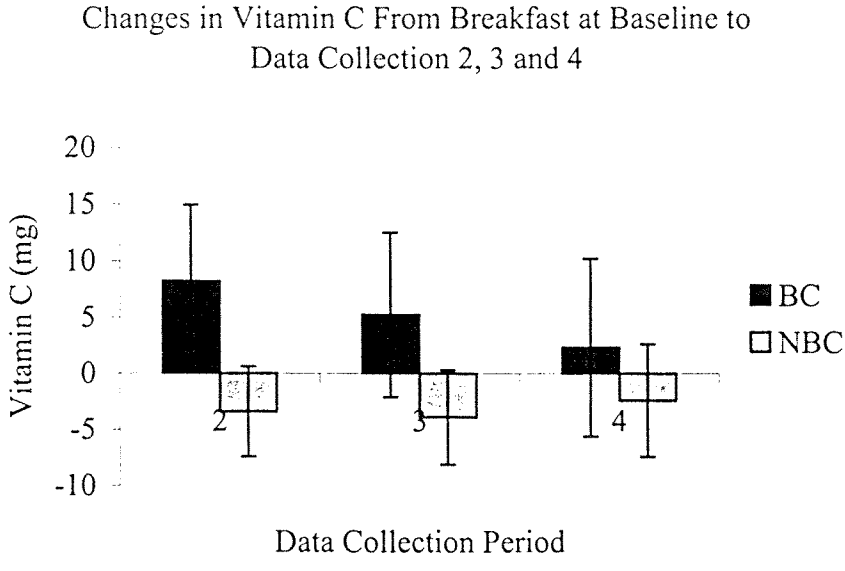


Figure: 3.2k Changes in Vitamin C From Breakfast at Baseline to Data Collection 2, 3 and 4

where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.00$

Vit A intake increased for the BC group at data collection points as shown in figure: 3.2m below.

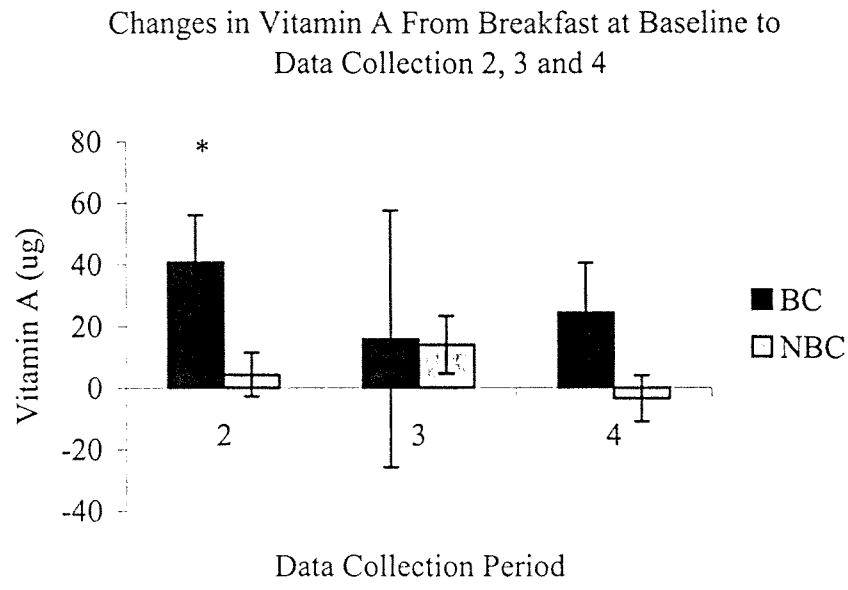


Figure: 3.2l Changes in Vitamin A From Breakfast at Baseline to Data Collection 2, 3 and 4
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

3.2.2 The Breakfast Meal Compared to Breakfast at Baseline

The breakfast consumed at baseline (when all breakfasts were eaten at home) was compared to the breakfasts eaten by the BC and NBC groups at data points 2, 3 and 4. The paired Student's t-test was used to compare baseline breakfasts for each group with the subsequent breakfast meals. Tables 3.2c and 3.2d below illustrate the differences between baseline breakfast and breakfast at each data collection point 2,3 and 4 for each of the BC and NBC groups. The differences found mirror the differences found between the groups when the change from baseline was explored.

Table: 3.2c Summary of the Macronutrient Differences of Breakfast at Baseline Versus Breakfast at Data Collection 2, 3 and 4 for the BC and NBC 2 Groups

	BC 20 Baseline Versus Data 2	NBC 20 Baseline Versus Data 2	BC 20 Baseline Versus Data 3	NBC 20 Baseline Versus Data 3	BC 20 Baseline Versus Data 4	NBC 20 Baseline Versus Data 4
Calories (Kcal)	✓		✓		✓	
% RNI Calories	✓		✓			
% Energy Fat						
Protein (g)					✓	
% RNI Protein	✓				✓	
Fat (g)						
PUFA (g)	✓					
% Energy PUFA	✓					
% RNI PUFA	✓		✓			
MUFA (g)	✓		✓			
% Energy MUFA						
% RNI Fat						
SAT	✓					
% RNI SAT	✓					
CHO(g)						
% RNI CHO						
Starch (g)						

where ✓ represents a significantly greater amount of nutrient at data 2,3 or 4 than the baseline measurement

and × represents a significantly smaller amount of nutrient at data 2,3 or 4 than the baseline measurement

Table:3.2d Micronutrient Differences Breakfast at Baseline Versus Breakfast at Data Collection 2, 3 and 4 for the BC and NBC groups

	BC 20 Baseline Versus Data 2	NBC 20 Baseline Versus Data 2	BC 20 Baseline Versus Data 3	NBC 20 Baseline Versus Data 3	BC 20 Baseline Versus Data 4	NBC 20 Baseline Versus Data 4
Calcium (mg)	✓		✓			
% RNI Calcium			✓		✓	
Vitamin C (mg)	✓					
% RNI Vitamin C						
Vitamin A						
% RNI Vitamin A	✓					
% RNI Vitamin B6						
Vit B_2			×			
% RNI B2			×			
Vit B_{12}			×			
% RNI vit B_1			×			
Folate						×

Where ✓ represents a significantly greater amount of nutrient at data 2,3 or 4 than the baseline measurement
And × represents a significantly smaller amount of nutrient at data 2,3 or 4 than the baseline measurement

3.2.3 Discussion

The significant increase in calories for the BC was due to the increase in cooked breakfasts of this group. There were only marginal differences in the calories for the NBC group because there were no significant differences in the type of breakfasts eaten by this group at baseline and at the subsequent data collection periods.

Whilst there were increases in the amount of CHO *per se* consumed at the breakfast meal for both groups there were decreases for the % energy from CHO for the BC group at data collections a 2 and 3. This was because of the change in the type of breakfast being consumed at the breakfast club i.e. children in this group were predominantly consuming cereal at baseline and consuming a cooked breakfast at data collections 2, 3 and 4. A high CHO breakfast can make a major contribution to a reduced fat intake for the entire day (Crawley, 1993) and this will be investigated in chapters 3.4 and 3.5.

Protein intakes increased for the BC group only. Again this was due to an increase in cooked breakfasts being consumed by this group, i.e. the increase in sausage, bacon, black pudding, eggs and cheese will increase the amount of protein in these breakfast.

The percentage of energy from fat had increased for the BC group since the baseline measurement. Again this was due to an increase in cooked breakfasts. The cooked breakfast included a hot filled roll which had 10g of either sunflower or olive spread which has had an impact on increasing fat intake at breakfast compared to the breakfast eaten at baseline. This is also reflected in the increase in PUFA and MUFA for the BC group. The increase in SFA is greater for the BC group than for the NBC group, due again to an increase in cooked breakfasts. Fat intakes at breakfast may have an impact on fat intake for the rest of the day and this will be examined in the subsequent chapters.

There were significant increases in Ca in the BC group at data collection 2 and 3. Milk was available as a drink at the breakfast club and was popular with the children till Summer when they preferred orange juice and cordial. The presence of subsidised milk at the breakfast club has increased Ca intakes for these 2 time periods. Vit C intake also increased for the BC group whilst there was a decrease for the NBC group, although the difference between the groups was not significant. Fresh orange juice was available at the breakfast club which has contributed to this increase in vit C and NDNS data has shown that fresh orange juice is the largest contributing food to vit C intakes in children (NDNS, 2000).

Vit A intakes had increased for the BC group since the breakfast at baseline. This was due to an increase in milk consumption and fortified margarine intake. The next chapter looks at the breakfast at baseline compared to the breakfast consumed by the breakfast at data collections 2,3 and 4and will explore if the differences between the groups still exists.

3.3 Total Daily Intake

Dietary intake was assessed using 3-day estimated food diary as described in chapter 2.3. The mean of the 3-days of intake was calculated and has been presented in this chapter for the BC and NBC groups.

The purpose of this chapter therefore is to investigate the differences between total dietary intake for the day for the BC and NBC group at baseline, data collection 2 ,3 and 4, and to investigate the difference between the groups (using independent t-tests). Dietary intakes have also been compared to RNIs. The change from baseline intake to daily intake at data collections 2 ,3 and 4 have also been explored and these are also represented in the tables below when statistically significant differences between the groups were found.

Table 3.3a Number of Subjects in the BC and NBC Group for the Breakfast Meal Nutrient Analysis

	Baseline	Data Collection 2	Data Collection 3	Data Collection 4
BC	110	23	26	27
NBC		65	68	72

Table: 3.3b Subject Characteristics of the BC and NBC Group for the Breakfast Meal Nutrient Analysis

	BC	NBC
Baseline		
Age	9.7(± 0.03)	
Gender	56F:54M	
Data Collection 2		
Age	9.8(± 0.4)	10.1(± 0.6)
Gender	12F:11M	35F:33M
Data Collection 3		
Age	10.1(± 0.5)	10.1(± 0.3)
Gender	13F:13M	38F:30M
Data Collection 4		
Age	10.1(± 0.4)	10.3(± 0.3)
Gender	23F:4M	36F:36M

Under Reporters

Estimated intakes were compared to BMR as described in chapter 2.3 and the percentage of children under-reporting could be calculated using a CUT-OFF point. At baseline we

can assume that 96% of the children were reporting their dietary intakes accurately. There was an average estimated intake of 664(± 103) kcal more than the BMR. There was only 4% of children under-reporting.

3.3.1 Daily Intake at Baseline

At baseline the children were consuming 1870.6 ±30.03kcals which is 94.5±1.9% of the RNI for calories. Of this 1870.6 kcals 37.7±0.5% of this energy was from fat. This is 115±1.5% of the RNI (35%) for fat ($p \leq 0.001$). SFA was a large proportion of this total fat at 14.2±0.3% of the total day intake and accounted for 142.7±3.2% of the RNI ($p \leq 0.001$). Percentage energy from PUFA was close to the RNI of 6.5% at 6.3%. Energy from MUFA was lower than the RNI (12.1% versus 13% where $p \leq 0.001$). Health professionals recommend that 50% of daily energy comes from carbohydrate (COMA, 1992) and in this group of children 47.3±1.0% of the energy came from this nutrient ($p \leq 0.01$). Daily recommended values (DRVs) for starch and sugar are 39% and 11% respectively. In this investigation there was only a 6% difference in % energy from starch and sugar with values at 27.3±0.5% and 21.3±0.5%. When compared to the DRVs there was a statistical difference ($p \leq 0.001$) for both nutrients. Protein accounted for 13.5±0.8 of energy for the day and intake was 58.3±1.5g which was 195.7±5.4% of the RNI. The percentage energy of macronutrients of total day intake at baseline is shown in figure 3.3a below.

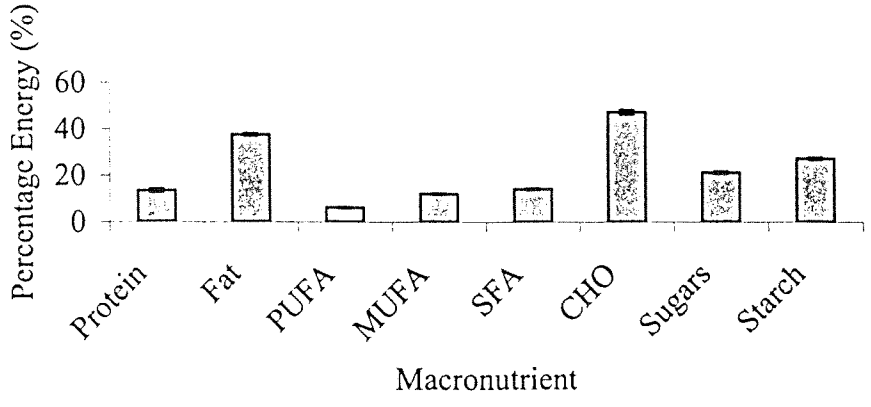


Figure: 3.3a Percentage Energy of Macronutrients of Total Day Intake At Baseline

Differences In Micronutrient Composition of the BC and NBC Groups for Total Day Intake at Baseline

Calcium intake was 735.4±88.9mg which is 12.7±3.4% over the RNI for the micronutrient. Fe is often available in insufficient amounts in the diets of school children and in this group 97.7±3.1% of the RNI was available. Vit C intake however was more than sufficient at nearly double the RNI (180.9±12.8%). The % RNI of micronutrients achieved by the children at baseline is illustrated in figure 3.4b below. The % RNI of vitamin A consumed by this group was 94.8±5.6%. Vitamin B_1, B_2 were plentiful and were both over the RNI by 71.3±7.1% and 15.4±4.4 respectively. Nicotinic acid, B_6 and B_{12} were all available at over double the RN1. Folate was present at 100.9% of the RNI

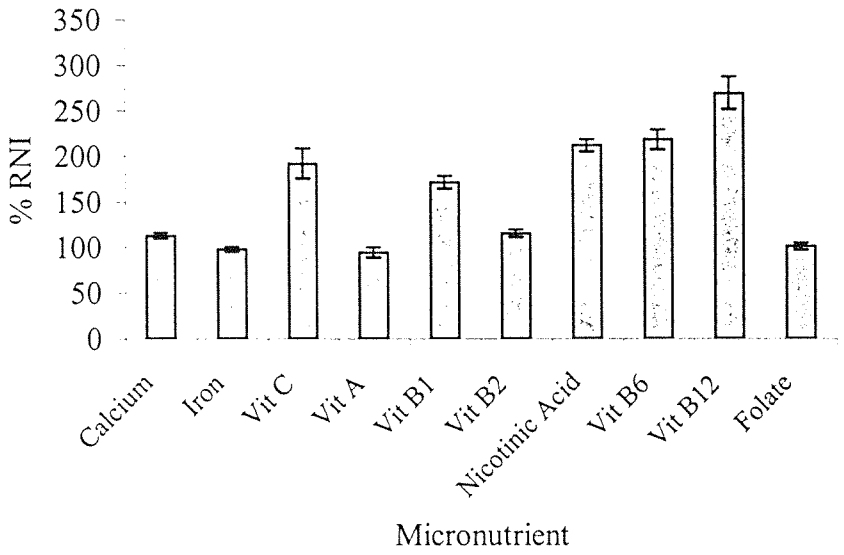


Figure: 3.3b The % RNI Micronutrients of Total Day Intake at Baseline

3.3.2 Differences in Daily Intake During Data Collections 2, 3 and 4 For the BC and NBC Groups

Differences in Daily Macronutrient Intake During Data Collections 2, 3 and 4 For the BC and NBC Groups

The BC group were consuming more calories than the NBC group at all 3 data collection periods. The difference between the groups was significant at data collection 3 (see figure 3.3c below).

Total Calorific Intake of the BC and NBC Groups

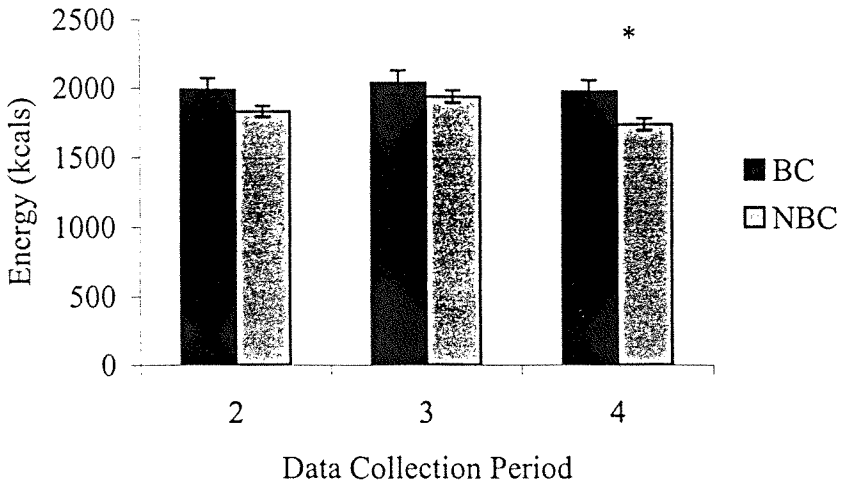


Figure: 3. 3c Total Calorific Intake of the BC and NBC Groups
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

The BC group tended to be closer to 100% RNI for calories than the NBC group as illustrated in figure: 3.4d below but the differences between the groups was not significant.

As shown in figure 3.3d the % energy from starch intakes was higher in the NBC group than the BC group but there was no difference between the groups for total carbohydrate.

Total Dietary % Energy Starch for the BC and NBC Groups

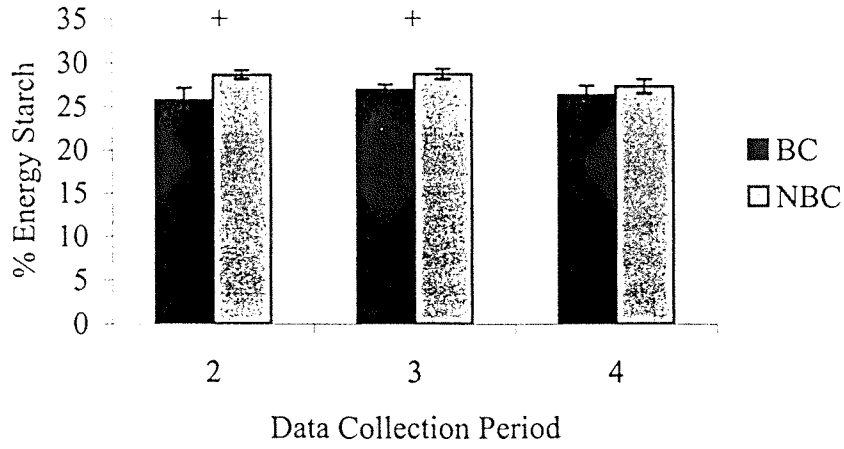


Figure: 3.3d Total Dietary % Energy Starch for the BC and NBC Groups
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

Total Calorific Intake of the BC and NBC Groups

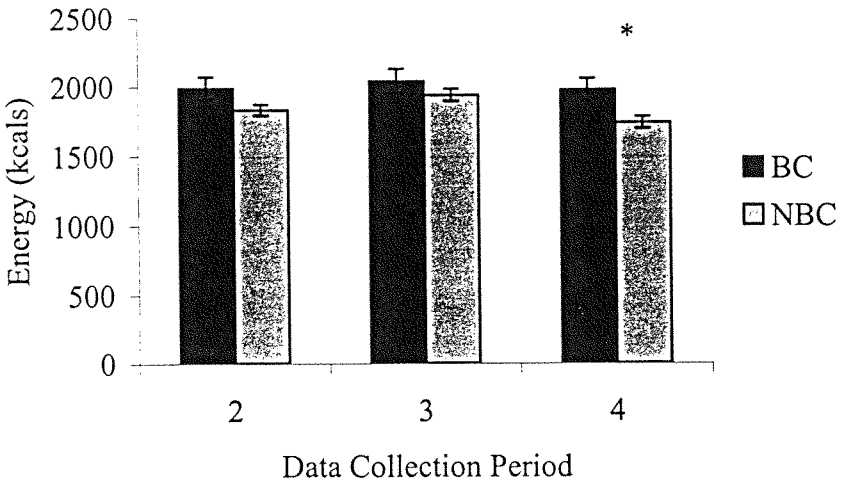


Figure: 3. 3c Total Calorific Intake of the BC and NBC Groups
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

The BC group tended to be closer to 100% RNI for calories than the NBC group as illustrated in figure: 3.4d below but the differences between the groups was not significant.

As shown in figure 3.3d the % energy from starch intakes was higher in the NBC group than the BC group but there was no difference between the groups for total carbohydrate.

Total Dietary % Energy Starch for the BC and NBC Groups

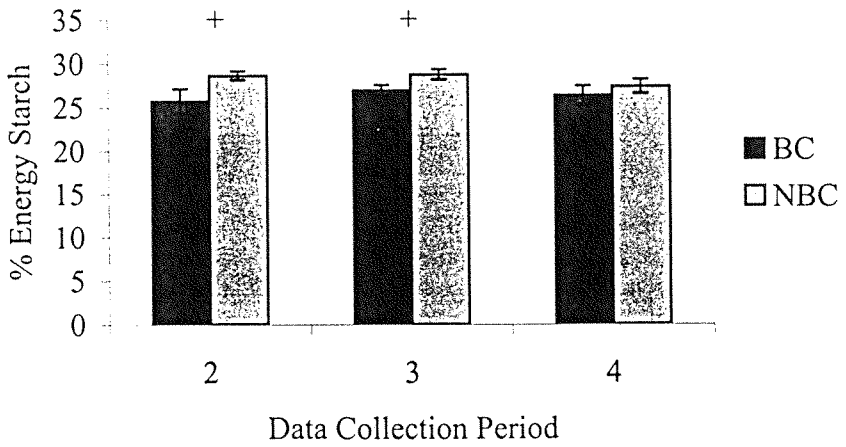


Figure: 3.3d Total Dietary % Energy Starch for the BC and NBC Groups
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

Total dietary fat was higher for the BC group than for the NBC group (see figure 3.3e below), however there was no significant difference in the % energy from fat between these 2 groups.

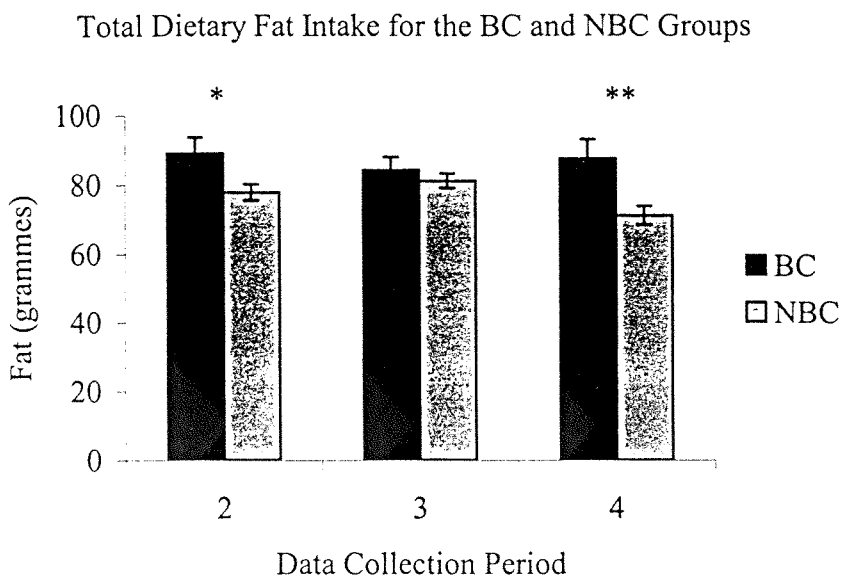


Figure: 3.3e Total Dietary Fat Intake for the BC and NBC Groups
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

There were statistically significant differences for the amount of PUFA in the breakfasts of the BC and NBC groups. Referring to figure:3.4f and 3.4g % energy PUFA and % RNI PUFA for the day was also a point of difference between the groups.

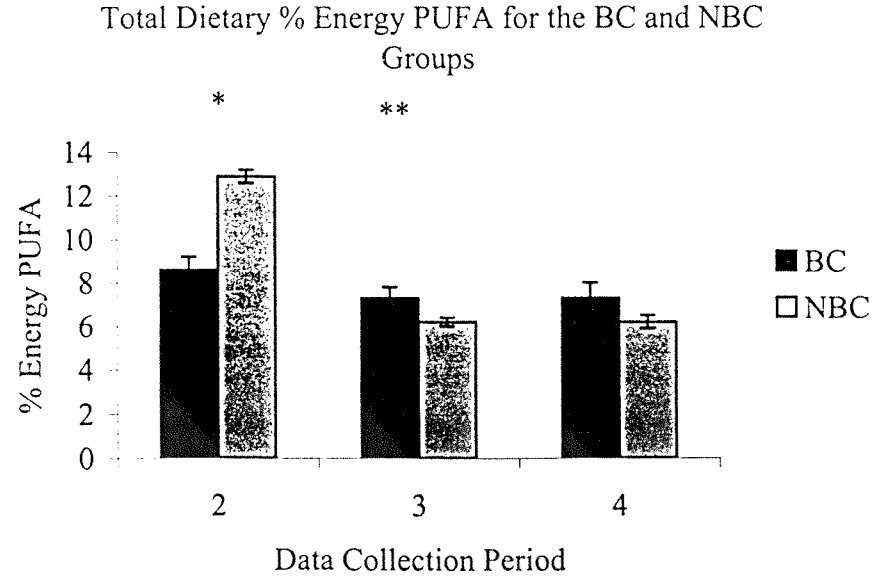


Figure: 3.3f Total Dietary % Energy PUFA for the BC and NBC Groups

where * $p \leq 0.05$, ** $p \leq 0.01$ and *** $p \leq 0.001$

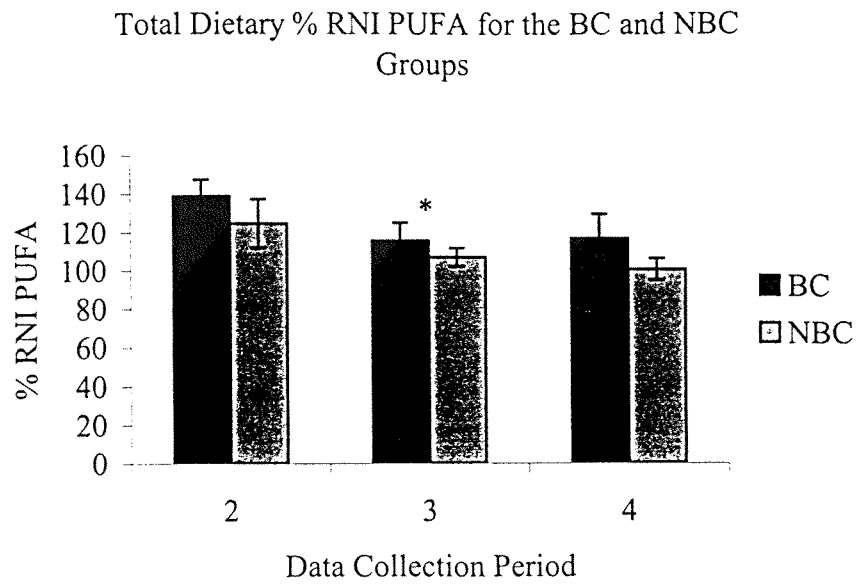


Figure: 3.3g Total Dietary % RNI PUFA for the BC and NBC Groups
where * $p \leq 0.05$, ** $p \leq 0.01$ and *** $p \leq 0.001$

As illustrated in figures: 3.4h and 3.4i MUFA intake for the day was also higher in the BC group than the NBC group.

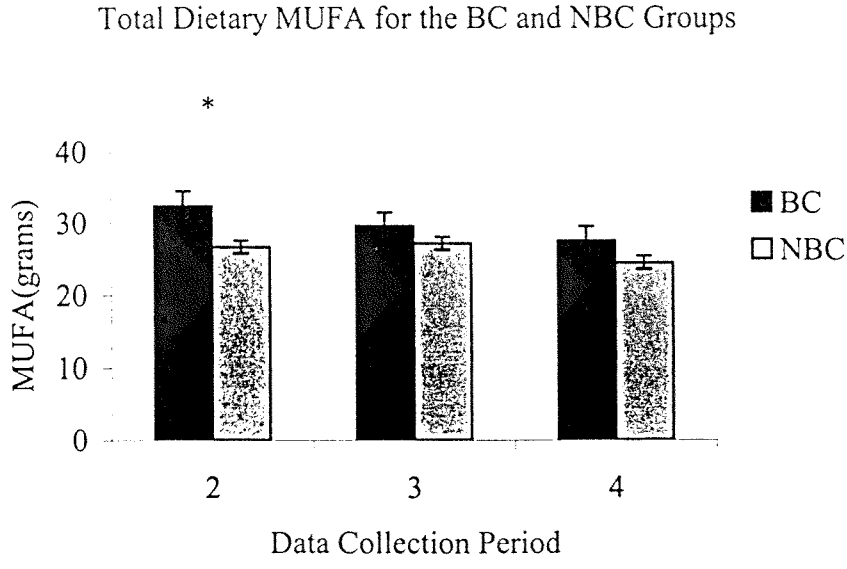


Figure: 3.3h Total Dietary MUFA for the BC and NBC Groups
where * $p \leq 0.05$, ** $p \leq 0.01$ and *** $p \leq 0.001$

Total Dietary Percentage Energy MUFA of Daily Intake

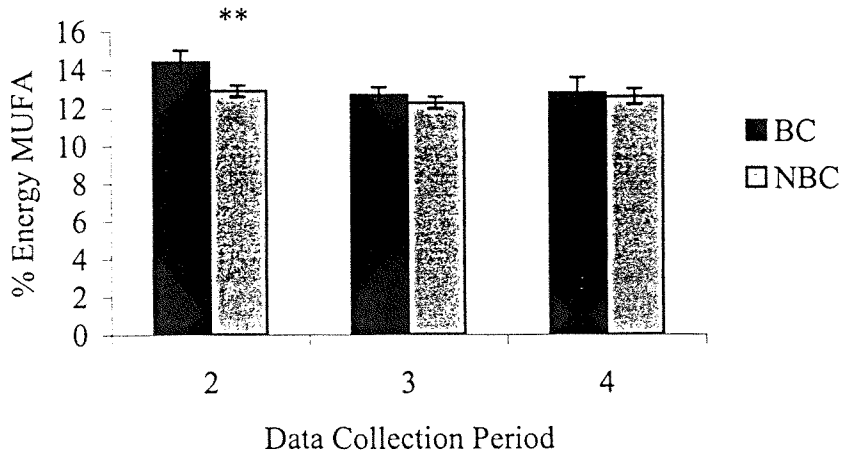


Figure : 3. 3i Total Dietary Percentage Energy MUFA of Daily Intake
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

Differences in Daily Micronutrient Intake During Data Collections 2, 3 and 4 For the BC and NBC Groups

Vitamin C intakes were higher at breakfast for the BC than the NBC group. This difference whilst not significant also manifested itself when total daily intake of vitamin was examines (see Figure: 3.4j below).

Total Dietary Vitamin C Intake

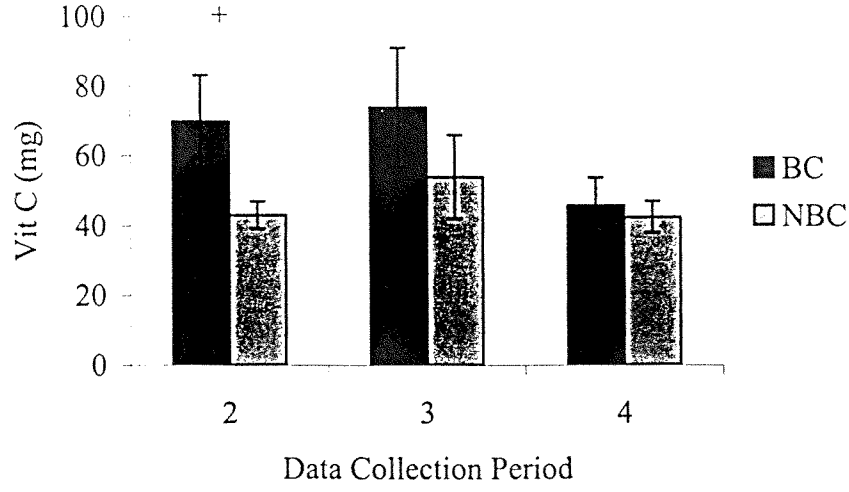


Figure: 3.4j Total Dietary Vitamin C Intake of the BC and NBC Groups
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

Nevertheless both groups were achieving over 100% of the RNI for this vitamin at all 3 data collection periods (see figure 3.2k below).

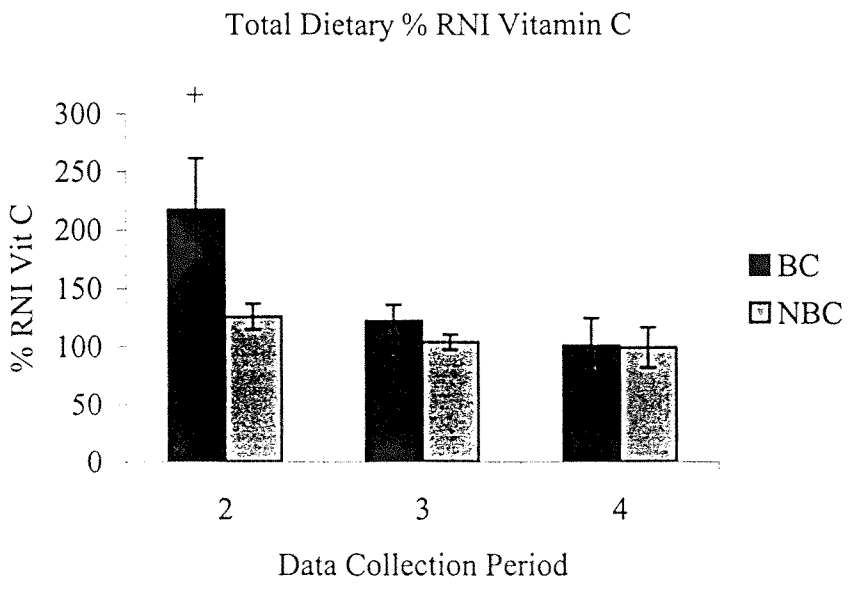


Figure: 3.4k Total Dietary % RNI Vitamin C
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

The children were below the RNI iron apart from the BC group at data collection 3(see figure:3.3l).

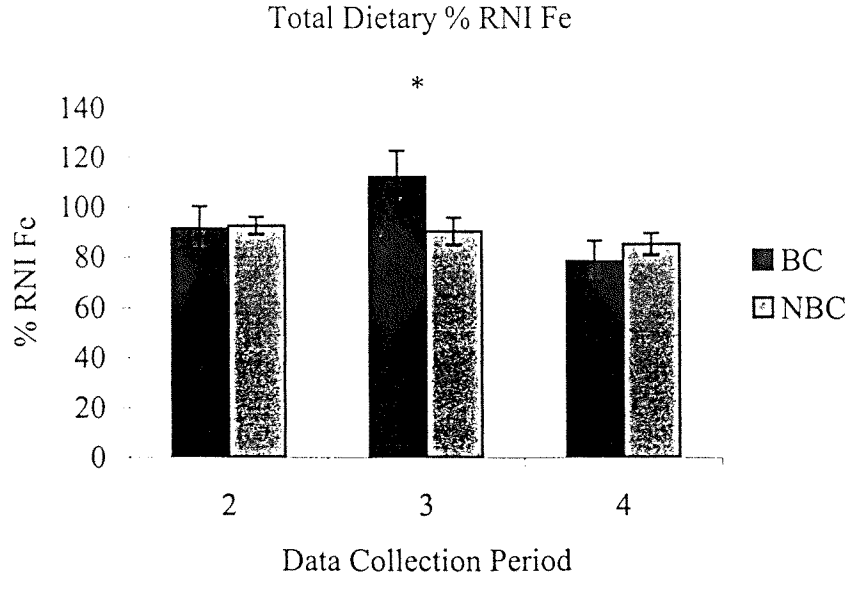


Figure: 3.3l Total Dietary % RNI Fe
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

3.3.3 Discussion

The BC group were consuming more calories than the NBC group at all 3 data collection periods. The difference between the groups was significant at data collection 3 (see figure 3.4c). This group were also eating more calories at breakfast at these 3 time periods (see chapter 3.1). The BC group were consuming significantly more cooked breakfasts than the NBC group who were cereal only eaters, and suggests that calorie intake at breakfast can affect calorific intake for the day. Gibson and O'Sullivan examined the effect of breakfast cereal consumption patterns and the nutrient intakes of British school children. Children were divided into non-consumers, light consumers (1-20g per day), medium consumers (20-40g per day) and heavy consumers (>40g). There was an increasing trend towards higher energy intake with greater cereal consumption (Gibson and O'Sullivan, 1995). In the present study the children who ate cereal had lower energy intakes. These findings are in-line with Cho's analysis of the Results of the Third Health and Nutrition Examination which found that people who eat meat and eggs for breakfast have the highest daily energy intake (Cho *et al.*, 2003) .

The BC group tended to be closer to 100% RNI for calories than the NBC group as illustrated in figure: 3.4d but the differences between the groups was not significant. In Ruxton's 1994 study of Scottish primary school children aged 7-8 years calorie intake was close to the RNI (Ruxton *et al.*, 1996). The latest NDNS has revealed that boys are achieving 91% of their RNI for calories whilst girls at getting 92% of their total energy requirements (NDNS, 2000).

Recommendations for CHO is that 50% of energy should come from this source (DRVs for Food Energy and Nutrients for the U.K, 1994). As illustrated in figure:3.4e , the NBC group were closer to this DRV than the BC group. The breakfasts of the NBC group were higher in % energy from CHO (due to a higher % of RTEBC) and so these results indicate that a breakfast high in CHO can lead to a higher % of energy for the day from this source.

In Ruxton's study children were classified into 3 groups; high RTEBC consumers (6-7 times a week), moderate RTEBC (4-5 times a week) and low RTEBC (0-3 times a week) and she fund that percentage energy from CHO increased with frequency of RTEBC consumption (Ruxton *et al.*, 1996).Whilst the present study has measured only 3-days of intakes the findings are reflect the findings by Ruxton. As illustrated in figure 3.4f starch intakes were also higher in the NBC group and it is recommended that 39% of energy comes from this source. Whilst none of the groups were achieving this recommendation the breakfasts of the NBC were higher in % energy starch and so were total daily intakes. This indicates again that breakfast can have an effect on nutrient intake for the day. Research has shown that a high CHO breakfast can make a major contribution to a reduced fat intake for the entire day (Crawley, 1993), and these results are in-line with this finding. Total dietary fat was higher for the BC group than for the NBC group (see figure 3.4i) and fat intakes at breakfast were also greater for this group. The DRV for fat is that it should provide no more than 35% of the total daily energy. Referring to figure 3.4g the NBC group was closer to this recommendation with an mean intake of 38% energy from fat, whilst the BC group were obtaining 43% energy from this source. Table 3.4f below summarises the findings of breakfast studies which have examined the differences in daily % energy from fat for high and low RTEBC consumers. Children in the present study who were in the BC group were placed in the low RTEBC group, whilst those in the NBC group form the high RTEBC group. Whilst not significant the 5% difference between the BC and NBC group is in-line with the 2-6% difference in daily fat consumption in the other studies. Data from the most recent NDNS show that 7-10 year old children are slightly over the DRV (they are getting 35.9% of their energy from fat, NDNS, 2000). The NBC group are thus close to the national average and the cooked breakfasts served at the BC club increased % energy from fat so that it was over the recommendations for healthy eating.

Table: 3.3c Differences in daily percentage energy from fat between 'high' and 'low' consumers of breakfast cereals

Study	Age (years)	Number	% Energy from fat		Significance of difference
			'High' RTEBC	'Low' RTEBC	
Present Study	7-11	113	38 (NBC)	43 (BC)	ns
Ruxton et al (1996)	7-8	136	36	40	$p \leq 0.001$
Morgan et al (1986a)	1-4	2191	38	40	$p \leq 0.05$
	13-17	3784	39	42	$p \leq 0.05$
Morgan et al (1981)	5-12	657	38	40	ns
Albertson and Tobelman (1993)	7-12	824	37	38	$p \leq 0.01$
Doyle et al (1994)	12-13	65	44	42	ns
Nicklas et al (1995)	10	568	35	37	ns
	8-18	504	33	37	$p \leq 0.005$
Gibson and O'Sullivan (1995)	10-11	1727	36	39	$p \leq 0.05$
	14-15	978	36	40	$p \leq 0.05$
Crawley (1993)	16-17	4760	40	43	$p \leq 0.001$
Kirk et al (1997)	18-23	48	29	35	$p \leq 0.05$
Morgan et al (1986b)	50-61	4865	41	44	$p \leq 0.05$
Zabik (1987)	>62	5490	38	43	$p \leq 0.05$

'High' RTEBC, consumers deemed to have a high intake of breakfast cereals in referenced paper; 'Low' RTEBC, consumers deemed to have a low intake of breakfast cereals in referenced paper.

There were statistically significant differences for the amount of PUFA in the breakfasts of the BC and NBC groups. This difference was attributable to the use of 10g of sunflower spread in the hot filled rolls at the breakfast club. The % energy PUFA and % RNI PUFA for the day was also appoint of difference between the groups. PUFA should constitute 6.5% of total daily energy and the BC group were over this recommendation at all 3 time periods, whilst the NBC group were close to the advised 6.5%. Increasing PUFA may

have beneficial consequences in lowering HDL cholesterol (Mensink *et al.,* 1990). However increasing any type of fat above the recommended amount should not be encouraged. The NDNS data revealed that 5.1% of total energy for 7-10year olds was from PUFA (NDNS, 2000), whilst Ruxton revealed that 5.3% of energy came from this source in the diets of 7-8 year old primary school children. The NBC group were this more in-line with the findings of the other studies and the breakfast club was thus increasing PUFA for the day above 'normal' intakes.

As illustrated in figures: 3.4k and 3.4j MUFA intake for the day was also higher in the BC group than the NBC group. This finding is also evident in the breakfast meals of these 2 groups. The recommendation that 13% of energy comes from MUFA is exceeded by the BC group at data collection 2, but both groups are close to this recommendations at data collections 3 and 4. SFA intakes between the groups were not significantly differently and both groups were above recommended 11%. These findings suggest that whilst a RTEBC breakfast may help to reduce overall % energy from fat, the diets of primary school aged children may need adjustments other than at breakfast in order to reduce SFA intake (e.g. school snacks and lunches should also be lower in SFA). If breakfast clubs have been set up to improve the diets of children then the nutritional profile of these breakfasts should be in-line with current healthy eating recommendations.

Vitamin C intakes were higher at breakfast for the BC than the NBC group. This difference whilst not significant also manifested itself when total daily intake of vitamin was examines. Fresh orange juice was available at the breakfast club and this had an effect of raising vit C intakes for the BC group. Results of the NDNS have showed that orange juice is the most important contributing food for vitamin C in children, and the findings of this study also reflect this. Nevertheless both groups were achieving over 100% of the RNI for this vitamin at all 3 data collection periods.

Iron intakes were below the RNI except for the BC group at data collection 3. Nutritional anaemia is one of the most common diet related deficiency disorder (Buttriss , 2002).

Young people are particularly vulnerable to iron deficiency (Department of Health (1991). Iron plays a significant role in the production of healthy blood cells. Moreover moderate to severe iron deficiency anaemia in children leads to reduced cognitive function, which can be improved by iron supplementation. (Deinard *et al.*,1985 and Pollitt *et al.*, 1985).A new British survey among almost 600 girls aged 11-18 years has found that mild iron deficiency anaemia can also affect cognitive function Ash and Nelson (in press). The finding that the children were below the RNI for this vital micronutrient is an area of concern.

Breakfast cereals and bread have been found to major contributors to iron intake accounting for about 50% of total intake, in the NDNS of young people (Buttriss, 2002), and this will be further explored in the next chapter.

3.4 The Contribution of Breakfast to Total Dietary Intake

Dietary intake was measured with a 3-day estimated diary as described in chapter 2.3. The mean values of total nutrient intake for the 3 days has been discussed in the previous chapter (chapter 3.3). The mean values of nutrient intake from the breakfast meal only for the 3 days have been discussed in chapter 3.1. In this present chapter nutrient intakes at breakfast were examined as a percentage of total day intakes as follows:-

$$\frac{\text{Mean of nutrient X at breakfast}}{\text{Mean of nutrient X for the total Day}} \times 100\% = \text{contribution of breakfast to total daily intake (\%).}$$

The purpose of this chapter is to:

1) investigate the contribution of the breakfast consumed by BC and NBC group to total dietary intake at baseline, data collection 2, 3 and 4.

Table 3.4a Number of Subjects in the BC and NBC Group for the Contribution of Breakfast Meal to Total Day Intakes

	Baseline	Data Collection 2	Data Collection 3	Data Collection 4
BC	110	23	26	27
NBC		65	68	72

Table: 3.4b Subject Characteristics of the BC and NBC Group for the Contribution of the Breakfast Meal to Total Day Intakes

	BC	NBC
Baseline		
Age	9.7(± 0.03)	
Gender	56F:54M	
Data Collection 2		
Age	9.8(± 0.4)	10.1(± 0.6)
Gender	12F:11M	35F:33M
Data Collection 3		
Age	10.1(± 0.5)	10.1(± 0.3)
Gender	13F:13M	38F:30M
Data Collection 4		
Age	10.1(± 0.4)	10.3(± 0.3)
Gender	23F:4M	36F:36M

3.4.1 The Contribution of Breakfast to Daily Intakes At Baseline

At the baseline measurement when all children consumed breakfast at home or on the way to school breakfast contributed 12.9±0.6 of calories, 15.8±0.6% CHO, 18.3±1.2% sugar, 15.6±0.7% starch, 13.2±0.9% protein, 9.2±0.8% of fat, and 11.8±1.3% of fibre for the day as shown in figure 3.4a. The breakfast meal provided 21.9±1.3 % of Fe intakes in the present study as illustrated in figure 3.4b below.

Contribution Of Breakfast Macronutrients to Total Daily Intake

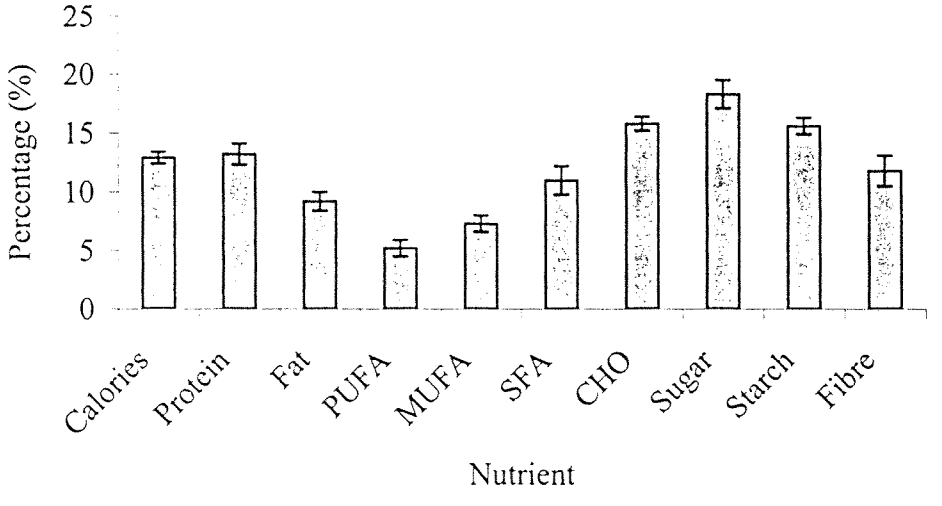


Figure: 3.4a Contribution Of Breakfast Macronutrients to Total Daily Intake

Figure: 3.4b Contribution of Breakfast Micronutrients To Total Daily Intake

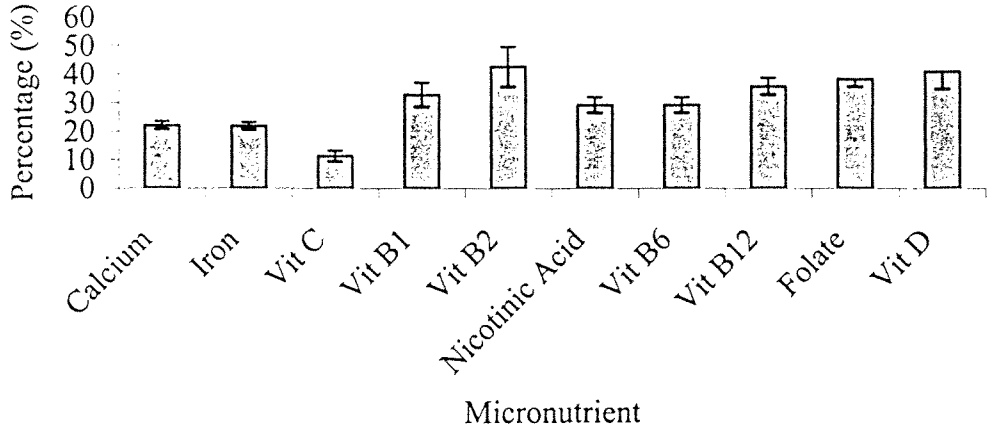


Figure: 3.4b Contribution of Breakfast Micronutrients To Total Daily Intake

3.4.2 Differences in the Contribution of Breakfast to Daily Intakes of the BC and NBC Groups

Breakfast contributed 12-14% energy intake at breakfast for the NBC group and 13-15% of total calories for the BC group (see figure 3.4c below.)

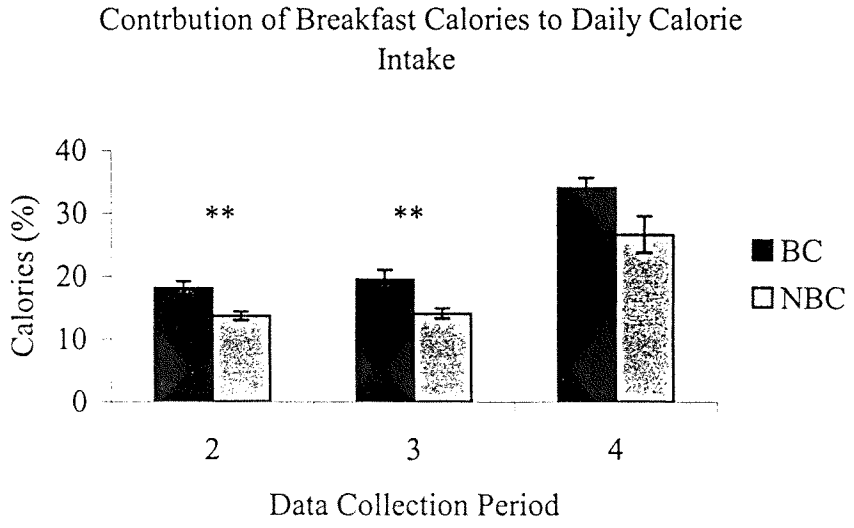


Figure: 3.4c Contribution of Breakfast Calories to Daily Calorie Intake
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

As shown in figure 3.4d below the BC breakfast contributed a higher % of fat to total daily intakes.

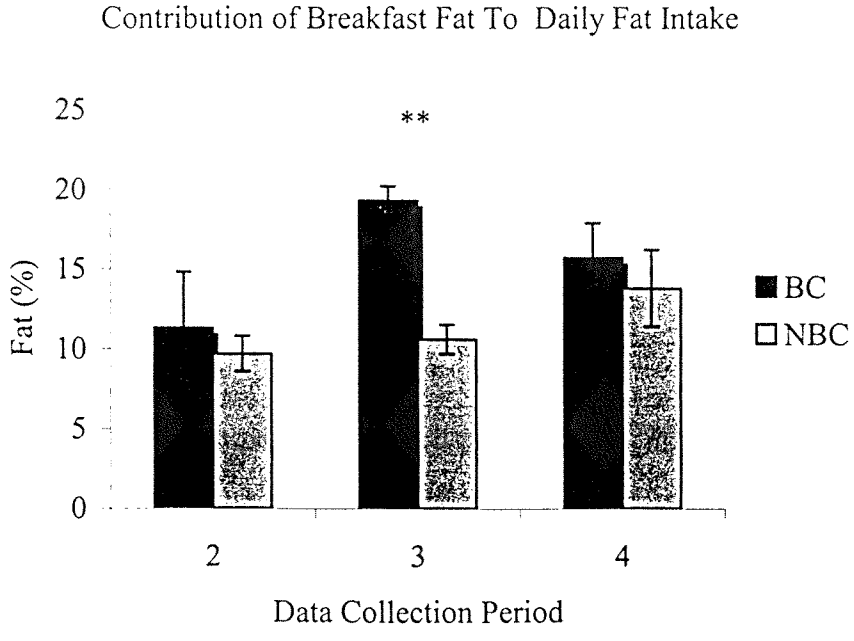


Figure: 3.4d Contribution of Breakfast Fat To Daily Fat Intake

where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

The % contribution of PUFA and MUFA from breakfast was higher in the BC group (see figures 3.4e and 3.4f below).

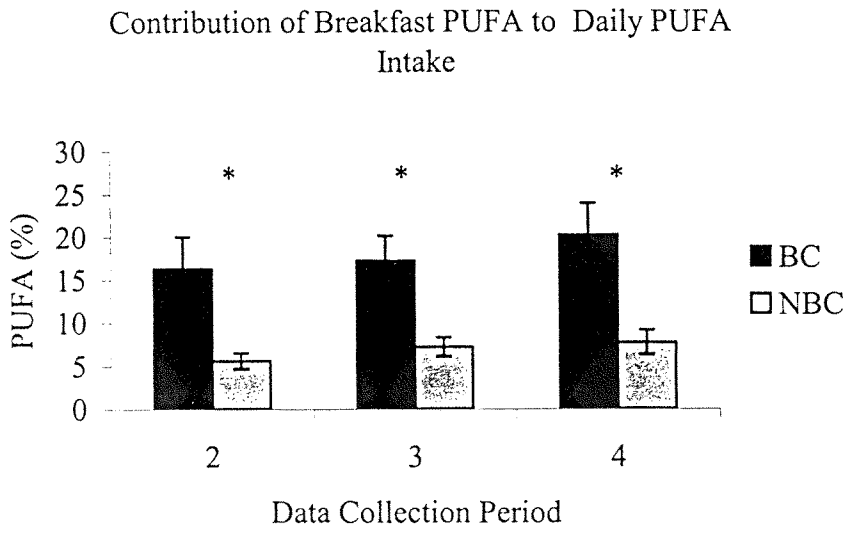


Figure: 3.4e Contribution of Breakfast PUFA to Daily PUFA Intake

where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

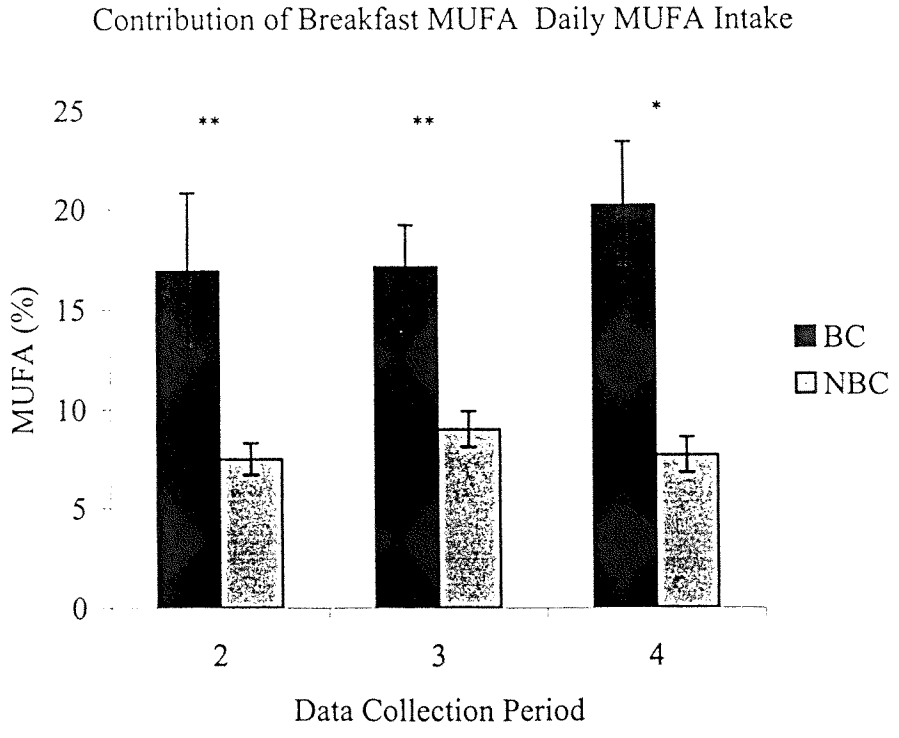


Figure: 3.4f Contribution of Breakfast MUFA Daily MUFA Intake

where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

The breakfast of the BC group contributed of SFA to the diet for the BC group than the NBC group (see figure 3.4g below).

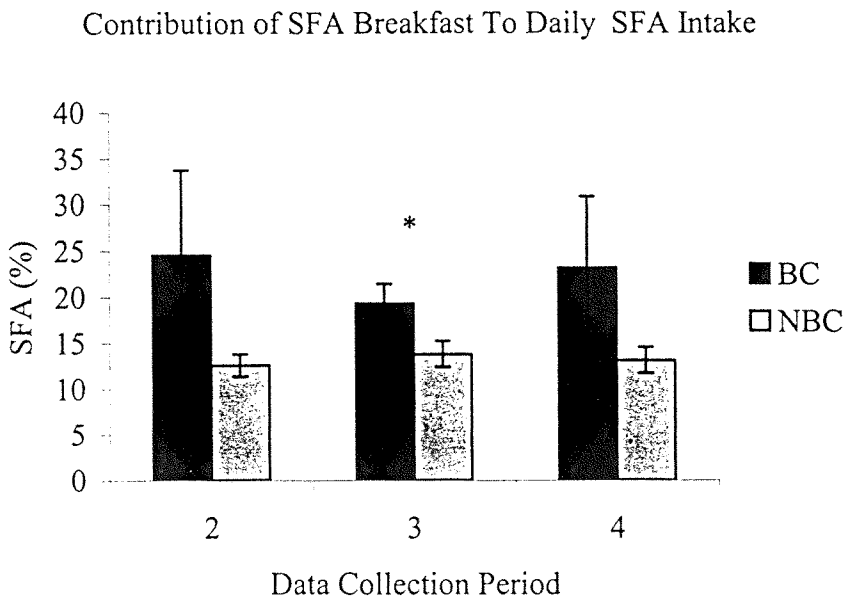


Figure: 3.5g Contribution of SFA Breakfast To Daily SFA Intake
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

The percentage energy from the breakfast meals from CHO was higher in the NBC group as illustrated in figure:3.h.

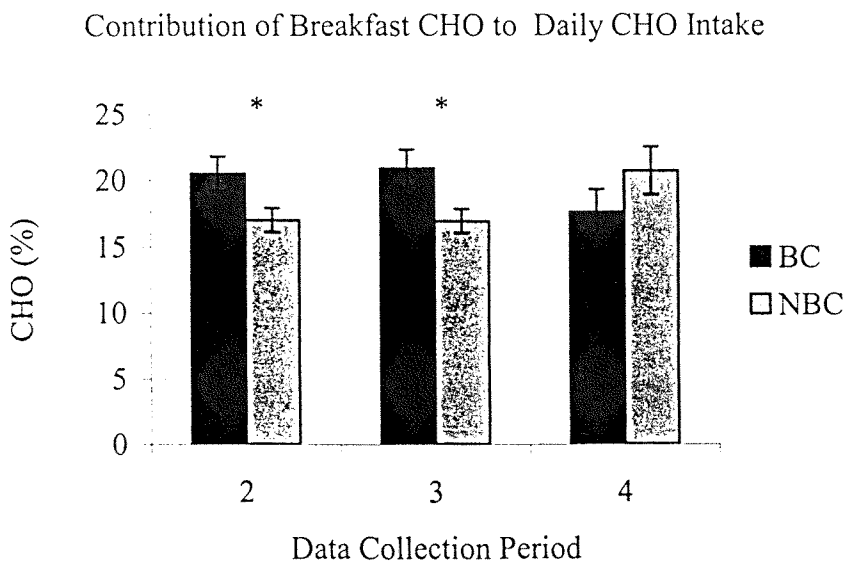


Figure: 3.4h Contribution of Breakfast CHO to Daily CHO Intake
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

The BC breakfast also contributed more vit C to daily intakes as shown in figure 3.4i.

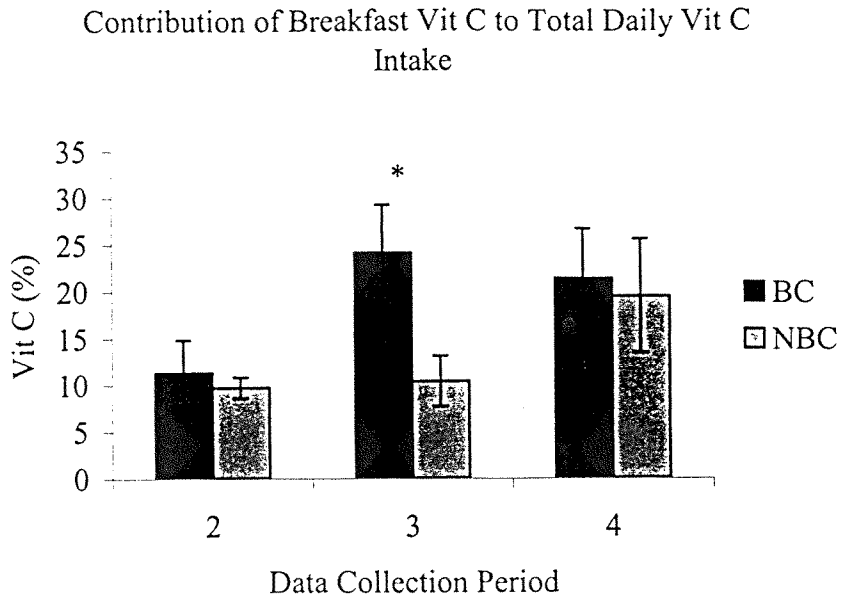


Figure: 3.4i Contribution of Breakfast Vit C to Total Daily Vit C Intake
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

The breakfast of the BC group provided more daily vit A as illustrated in figure 3.5j below.

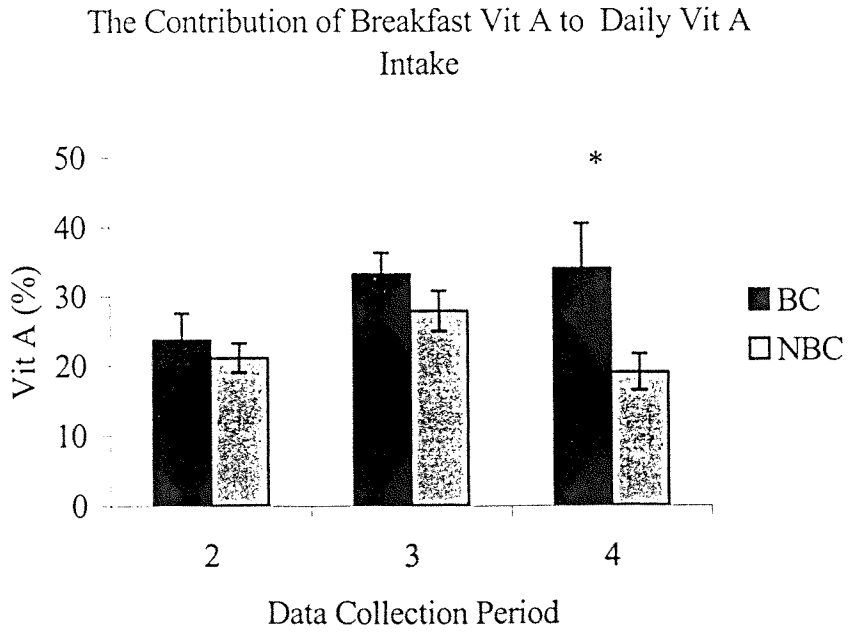


Figure: 3.4j The Contribution of Breakfast Vit A to Daily Vit A Intake
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

The NBC breakfast contributed a higher % of vitamin B2 at data collections 2 and 3 as shown in figure 3.4k below.

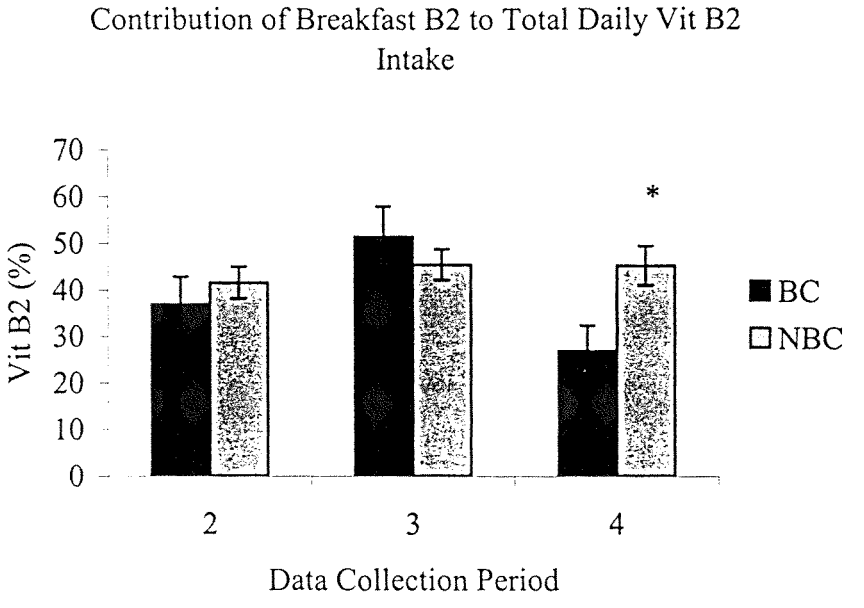


Figure:3.4k Contribution of Breakfast B2 to Total Daily Vit B2 Intake
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

3.5.3 Summary

Healthcare professionals advise that 20% of nutrient intake should come from the breakfast meal . At the baseline measurement when all children consumed breakfast at home or on the way to school breakfast contributed 12.9±0.6 of calories, 15.8±0.6% CHO, 18.3±1.2% sugar, 15.6±0.7% starch, 13.2±0.9% protein, 9.2±0.8% of fat, and 11.8±1.3% of fibre for the day as shown in figure 3.5a. At this point 52% of the children were eating a cereal only breakfast over the 3 –days of data collection and 6 % were eating a cooked breakfast. Only 12% of children at baseline were not eating breakfast cereal for breakfast at least once over the course of the 3-days. Whilst all macronutrients were below the recommended 20% breakfast contributed to over 20% of the macronutrients measured except for vitamin C (see Figure 3.5b). The breakfast meal provided 21.9±1.3 % of Fe intakes in the present study and this finding was in-line with Gibson analysis of pre-school children where breakfast cereals provided 20% of the total Fe intake of the pre-school children (Gibson, 1999).

.In her 1991 study of 136 Edinburgh school children Ruxton found that breakfast contributed 14% of energy (Ruxton, 1996). This finding is in line with the 12-14% energy intake at breakfast for the NBC 20 group. Livingstone found that breakfast supplied 6% of energy intake in 5-9 year olds, while there was a 20% contribution to calories for 8 year olds (Margarey *et al.*, 1987) and 16% for 10-15 year olds by Spyckerelle *et al.* (1992). Morgan *et al.* reported that children aged 5-12 years consumed 18% of their calories at breakfast (Morgan 1986).

Greer revealed that children 4-5 years of age consumed 22% of their calories at breakfast if they ate cereal a and 24% if their breakfasts did not contain cereal (M.S Thesis, 1990). The lower contribution of calories from the cereal breakfast is evident in the present study also.

There were no significant differences in protein intake between the groups although intakes were higher for the BC group and closer to the recommended 20%. Protein intakes were higher in the BC group because more children were consuming a cooked breakfast (sausage, bacon, black pudding ,egg filled roll or cheese toastie) at this point than the NBC 20 who were consuming more cereal. In the NDNS of young people cereal and cereal products contributed to just over quarter of protein intakes (Buttriss, 2002). Ruxton's breakfast analysis found that this meal contributed 16 % of protein intakes, whilst Navia study of children aged 2-6 years found that breakfast contributed to 13.5% of total protein intake. Morgan also found that breakfast provided children with 16% of their protein intake (Morgan *et al.*, 1986).

As shown in figure 3.5d below the BC breakfast contributed a higher % of fat to total daily intakes. Since fat intakes in these children were above the recommended amount this contribution from breakfast is not a positive outcome. Reducing fat intake to below 35% has been a national health focus for many years. Reducing the % of fat at the breakfast meal therefore may play a part in helping to reduce fat intakes for the day. A multivariate

analysis by Gibson *et al.* (1995) of the DoH's survey of the Diets of British schoolchildren identified one pattern of food consumption that was correlated with a high percentage energy from fat. This pattern was characterised by a high intake of butter and white bread, and a low intake of breakfast cereals and milk, suggesting that in children breakfast consumption may be a positive indicator of a low fat diet (Gibson *et al.* 1995). In an analysis of the NDNS Gibson found that breakfast cereals alone make a low contribution to fat intake (1%) but a good contribution to CHO intake (11% in boys and 8% in girls) (Gibson, 2003). Fat intake at breakfast in this study has been shown to contribute to total fat intakes for the day and guidelines for maximum fat content of breakfast meals for school breakfast clubs should be taken into consideration to ensure that this meal does not detrimentally increase fat intakes for the day.

The use of sunflower and olive spreads at the breakfast clubs meant that the BC group had higher intakes of PUFA and MUFA at the breakfast meal and for the rest of the day. The breakfast meal of the BC group also contributed a greater % of these fats to total daily intake. Whilst this meant that the breakfast meal provided closer to the recommended 20% the intake of these fats was too high in both group but more so in the BC group (see figures 3.5 e and 3.5 f below).

The breakfast of the BC group contributed more than the recommended 20% of SFA to the diet for the BC group (see figure 3.5). This is a worrying trend since high SFA levels are associated with serum cholesterol and the association between CHD mortality is closest with SFA. The BC group had a higher percentage of cooked breakfast eaters and so this finding is expected. Research has shown that children who consume breakfast cereals for breakfast have lower blood cholesterol levels (Reniscow, 1991).

The percentage energy from the breakfast meals from CHO was higher in the NBC group. Despite this CHO *per se* at breakfast was greater for the BC group, and the breakfast meal of this group contributed a higher percentage of CHO at data collections 3 and 4 (see

figure 3.5h). Research has shown that a breakfast which has a high % energy CHO can make a major contribution to a reduced fat intake for the day (Crawley, 1993, Sommerville *et al.* 1993 and Gibson *et al.* 1995). Whilst the BC 20 group had higher CHO intakes *per se* as compared to the NBC 20 groups the % energy CHO of these breakfast was lower than the NBC 20 groups and the fat was higher. As discussed the fat intakes of the NBC 20 group were lower than that of the BC 20 and so we can conclude that this study is in agreement with the aforementioned studies. After the commencement of the breakfast club the contribution of CHO from breakfast to total CHO intake was 19.5% for the BC 20 group and 18.5% for the NBC 20 group. Magarey found that breakfast provided 19% of CHO in the study looking at breakfast intake of 11 year olds (Magarey *et al.*) whilst Ruxton found that breakfast provided 7-8 year old children with 18% of their CHO intake.

Ca intakes at breakfast have traditionally been high since cereal consumption encourage the consumption of milk). Eating a cereal breakfast with milk is an effective way to increase Ca intake which is an important mineral for children and teenagers for the development of strong bones and teeth Nicklas et al. (1998). Fortified foods such as breads and breakfast cereals also provide 30% adult calcium intakes (NDNS 2002). At data collections 3 and 4 both groups were consuming a breakfast tat provided over 20% of Ca intakes. Intakes at the BC were high due to the consumption of milk as a drink at the breakfast club.

The breakfast meal provided over 20% of the Fe intake for both groups of children. The source of Fe in the BC group was the meat and in the NBC group fortified RTEBC contributed a high percentage of Fe. They are the single biggest source of Fe (26%) in the young persons diet, providing more iron than meat and meat products (13%), breads (13%) or vegetables (17%) (NDNS, 2000). Nutritional anaemia is one of the most common diet related deficiency disorders (Buttriss, 2002) and young people are particularly vulnerable to Fe deficiency. In the NDNS of young people , 13% of all boys and 14% of all girls had

low Fe stores (Buttriss, 2002). Therefore it is of major importance that children receive enough of this mineral. Fe intake at breakfast is therefore essential.

The BC breakfast contributed a higher amounts of vit C for the BC group due to the consumption of fresh orange juice and this group were closer to the recommended 20% from breakfast. The consumption of fresh juice at breakfast clubs should be promoted.

The breakfast of the BC group provided more than 20% of daily vit A intakes and the fortification of the margarine used at the breakfast clubs had an effect on increasing this vitamin. The diets of the NBC group were below the RNI for this vitamin. Whilst the breakfast club increased intakes of this vitamin it also increased fat intakes.

The NBC breakfast contributed a higher % of vitamin B2 at data collections 2 and 3. RTEBC eaters have improved B-vitamin status and this has been shown in a number of studies (Preziosi et al 1999, Gibson and O'Sullivan , 1995, Gibson, 2003).

4.1 Cognitive Performance

Cognitive performance of the breakfast club (BC) and non-breakfast club (NBC) were explored. Cognitive performance as discussed in chapter 1 refers to short-term memory, sustained attention and mental computation . This was measured using subtests from the Wechsler Intelligence Scale for Children-III^{uk} (WISC-III^{uk}). The rationale regarding the choice of this psychological test have also been discussed in detail in chapter 2.

The subtests of this test that were used were:-

1) Digit Span where the subjects recalled a series of items in forward and reverse order as a test of short-term auditory memory.

2) Coding where subjects replaced digits with symbols and this test represented the discrimination of memory and visual pattern stimuli.

3) Arithmetic which measured mental computation and concentration.

The Arithmetic and Digit Span scores have also been added together and converted to give the Freedom from Distractibility Index (FDI) which has been used as a clinical indicator of Attention Deficit Hyperactivity Disorder (ADHD). The meaning of the FDI has been the topic of extended debate (Dockrell, 1992) and has been discussed in detail in chapter 2. FDI scores of the BC and NBC group at data collection 2,3 and 4.

Cognitive function was measured at baseline before the commencement of the breakfast club. After the breakfast clubs opened in 2 of the schools there were 3 subsequent measurements at approximately 6 weeks apart. These data collection periods are shown below as data collection 2, 3 and 4.

The raw scores of the Digit span, Coding and Arithmetic subsets of the WISC-III^{uk} have been age scaled and the results of the BC and NBC at data collection 2, 3 and 4. There were no differences between the BC and NBC groups (using independent t-tests).

Scores at Data Collection Periods 2,3 and 4 Compared to Baseline

Baseline scores for Digit Span, Coding and Arithmetic subsets from the BC and NBC groups were compared to scores at data collection periods 2,3 and 4 using the paired students t-test to assess the difference between baseline scores and scores at the subsequent measurements. The baseline score for the BC and NBC group have been represented below by Baseline BC and Baseline NBC respectively. BC and NBC refers to the score by the breakfast club group and non-breakfast club group at that particular time period.

The data was also divided by gender to explore any differences that might have existed between the sexes The total population representing both boys and girls of the BC and NBC groups have been presented in the tables below.. Although there are no separate norms for the sexes research by Slate and Fawcett (1996) demonstrated there were differences between girls and boys and that these were substantial enough to influence learning disability diagnosis.

Since the study was a free-living investigation there were fluctuations in the subject numbers and characteristics when the scores at baseline were compared to scores at data collections 2 , 3 and 4. These differences are shown in tables 4.1a to 4.1c below.

Table: 4.1a Subject Descriptives for Data Collection 2 versus baseline

	BC	NBC
Total Population	17	82
Age of Total Population	9.9(±0.26)	9.9(±0.11)
Girls	9	41
Age of Girls	9.9(±0.34)	10.0(±0.15)
Boys	8	41
Age of Boys	10.0(±0.42)	9.9(±0.16)

Table: 4.1b Group Descriptive for Data Collection 3 versus baseline

	BC	NBC
Total Population	24	69
Age of Total Population	9.8(±0.22)	10.2(±0.12)
Girls	13	36
Age of Girls	9.7(±0.27)	10.3(±0.15)
Boys	11	33
Age of Boys	9.9(±0.27)	10.0(±0.20)

Table 4.1c : Subject Descriptive for Data Collection 4 versus baseline

	BC	NBC
Total Population	28	66
Age of total Population	10.0(±0.20)	10.3(±0.13)
Girls	14	34
Age of girls	10.1(±0.25)	10.4(±0.17)
Boys	14	32
Age of Boys	10.0(±0.32)	10.3(±0.20)

4.1.1 Cognitive Functions Scores at baseline compared with scores at data collection 2,3 and 4

When baseline scores were compared to scores at data collection 2 there was an improvement for the BC group for the digit span test ($p \leq 0.05$). At data collection 3 there were more pronounced improvements for the NBC group for the digit span, coding and arithmetic tests and the FDI ($p \leq 0.001$.) Similarly there were more pronounced improvements for the coding, arithmetic and FDI score for the NBC group at data collection 4.

Table: 4.1d Cognitive Function Scores at baseline compared with results at data collection 2,3 and 4 for the BC and HB Group

Data	WISC Subtest	Baseline BC	BC	Baseline NBC	NBC
2	Digit Span	8.39(±0.73)	9.44(±0.62)*	9.64(±0.34)	9.51(±0.34)
3	Digit Span	8.91(±0.60)	9.82(±0.58)$^{+}$	9.42(±0.39)	10.63(±0.38)***
	Coding	6.30(±0.56)	6.96(±0.50)	6.39(±0.27)	7.14(±0.29)***
	Arithmetic	7.43(±0.58)	9.61(±0.63)*	8.55(±0.41)	10.15(±0.33)***
	FDI	89.7(±2.75)	97.9(±2.45)**	95.3(±1.81)	102.9(±1.77)***
4	Coding	6.65(±0.50)	7.69(±0.51)$^{+}$	6.21(±0.24)	7.36(±0.27)***
	Arithmetic	8.12(±0.65)	10.65(±0.80)**	8.29(±0.39)	10.78(±0.44)***
	FDI	91.8(±2.85)	101.4(±2.88)*	94.4(±1.88)	103.1(±1.88)***

Significant differences between baseline scores and scores at collection 2,3 and 4, as measured by the repeated measures t-test where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$, $^{***}p \leq 0.001$, $^{+}$ p=0.05-0.06.

The data was divided by gender to see is there were any differences between the sexes. The significance levels of the cognitive performance score improvements are shown below in tables 4.1e and 4.1f. It appears that girls show a greater degree of improvement from their baseline scores in both the BC and NBC groups.

Table: 4.1e Significance levels of Cognitive Performance Score Improvements from Baseline To Data Collection 2,3 and 4 for Girls BC and NBC Groups

Baseline Versus	BC				NBC			
	Digit	Coding	Arith	FDI	Digit	Coding	Arith	FDI
Data 2				*				
Data 3			+	*	*	***	**	**
Data 4		***	*	*		***	**	*

Where * $p \leq 0.05$
** $p \leq 0.01$
*** $p \leq 0.001$
+= trend where $p \leq 0.051$-0.06

Table: 4.1f Significance levels of the Cognitive Performance Score Improvements from Baseline To Data Collection 2,3 and 4 for Boys BC and NBC Groups

Baseline Versus	BC				NBC			
	Digit	Coding	Arith	FDI	Digit	Coding	Arith	FDI
Data 2		*			*			
Data 3	*						***	**
Data 4						*	***	**

Where * $p \leq 0.05$
** $p \leq 0.01$
*** $p \leq 0.001$
+= trend where $p \leq 0.051$-0.06

4.1.2 Discussion

There were improvements for the digit span and coding score for the total population of the BC group from baseline to data collection 2 (see table 4.1d). These improvements could be due to a change from the normal breakfast eaten by this group. This may not be due to nutrient changes (to be explored in the next chapter) but due to the extra attention given to the children at the breakfast club. At the third data collection point there were more marked improvements for the NBC group than the

BC group for all scores. In order to elucidate whether this was due to the difference in nutrient intake at breakfast the difference between the breakfasts must be explored (see chapter 4.2 and 4.3). At data collection 4 there were still more significant improvements for the NBC group than the BC group. Also girls seemed to show more pronounced improvements overall . Their performance could be more sensitive to nutrient changes than boys which could indicate that there is a differences between the sexes or merely that the girls in this study were more sensitive to changes in nutrient intake at breakfast.

In order to assess the possible influences that the nutrient content of the breakfast meal of these 2 groups may have had on the test scores, it is necessary to look at the differences in breakfast between the BC and NBC groups. Whilst chapter 4.1 has already explored the differences between the breakfast for the 3-days that this meal was assessed, the breakfast on the actual day of cognitive performance testing must be investigated in order to explore tests scores and nutrient intake. This is because cognitive performance in well nourished populations is likely to be affected by the short term intake of food. As outlined in chapter 1 the specific content of food affects certain biochemical and hormonal functions in the body and brain, thus linking diet to behaviour and cognition. In fact rapid and specific changes in brain composition normally occur after each meal (Wurtman *et al.*, 1974).

The next chapter (4.2) describes the differences between the breakfasts of the BC and NBC breakfast on the day of testing and significant changes from the baseline breakfast before the commencement of the breakfast club for each group. In order to differentiate this particular meal from the analysis of the 3-days of breakfast it has been designated the term 'cognitive breakfast'.

4.2 Cognitive Breakfast

The breakfast consumed on the morning of cognitive function testing is detailed in this chapter and is referred to as the 'cognitive breakfast'. The nutritional results of this breakfast was included in the mean for the calculation of the 3-days of breakfast analysed in Chapter 3.1. Access to the breakfast club register and the timetable of test days has enabled the breakfast eaten on the day of psychological testing to be investigated alone. The differences between the breakfast club group (BC) and non-breakfast club group (NBC) has been explored below using independent t-tests.

The purpose of this chapter is to:

(1) investigate the nutritional differences of the breakfasts consumed by the BC and NBC groups on the morning of cognitive performance testing

Subject Numbers Characteristics

Chapter 4.1 examined the difference between the cognitive performance test scores of the BC and NBC groups. Since this chapter aims to investigate the difference in breakfasts between the 2 groups subjects number and characteristics are the same as the previous chapter.

4.2.1 Breakfast Consumption at Baseline

As shown in figure 4.2a below at baseline 59% of children were eating RTEBC at the cognitive breakfast meal, and only 6% ate a cooked breakfast.

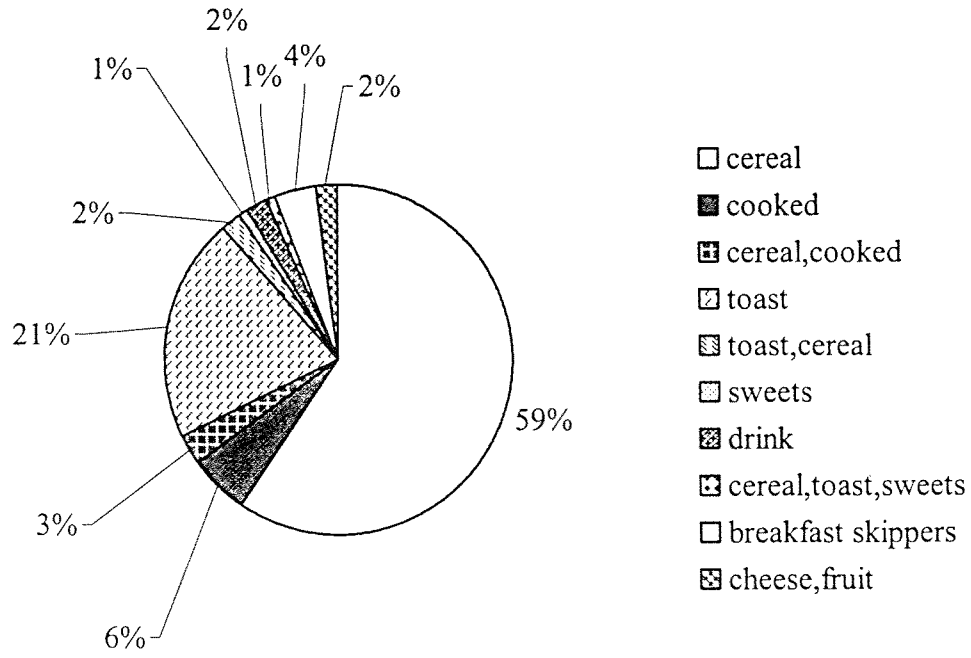


Figure 4.2a Pie-chart of Cognitive Breakfast Types at Baseline

The Macronutrient Composition of Breakfast at Baseline

At baseline breakfast provided 236.8 ±11.6kcal. This accounted for 12.1±0.6 of the RNI for calories. Percentage energy from protein was 11.7 ±0.5% and 22.5±1.4% of the energy for this meal was from fat. The largest source of energy was from CHO at 61.9%.

There were 6.6±0.6 of fat in the breakfast at baseline. Saturated fat was the largest contributor to the total fat intake at 2.9±0.3g accounting for 10% of energy. Percentage energy from MUFA and PUFA was 5.9±0.5g and 2.0±0.3g Starch and sugar was present in the breakfast meal in approximately equal amounts. This is illustrated in table 4.2 a below

The Micronutrient Composition of Breakfast at Baseline

Calcium was present in the baseline breakfast at 23.4%(±1.4) of the RNI. A similar % of the RNI for Fe was available in this meal at 20.4%(±1.4). The % of RNI for vitamin C was 38.2%(±1.4). Over 10% of the RNI for vitamin A was met by the breakfast meal. Approximately 40% of the RNI for vitamin B1 and nicotinic acid was provided by baseline breakfast. The % of the RNI for vitamins B2 and B12 was greater at 48.4%(±4.9) and 66.4%(±6.3) respectively. The largest % for RNI was meet by vitamin B6 at approximately 70%. There were 2.5ug(±5.9) of vitamin D present in the baseline breakfast.

4.2.2 Nutrient Intake at Breakfast on the Day of Cognitive Performance Testing for the BC and NBC groups at data collections 2,3 and 4

The types of breakfast eaten by the BC and NBC groups on the morning of cognitive testing are illustrated below (figure: 4.2b).

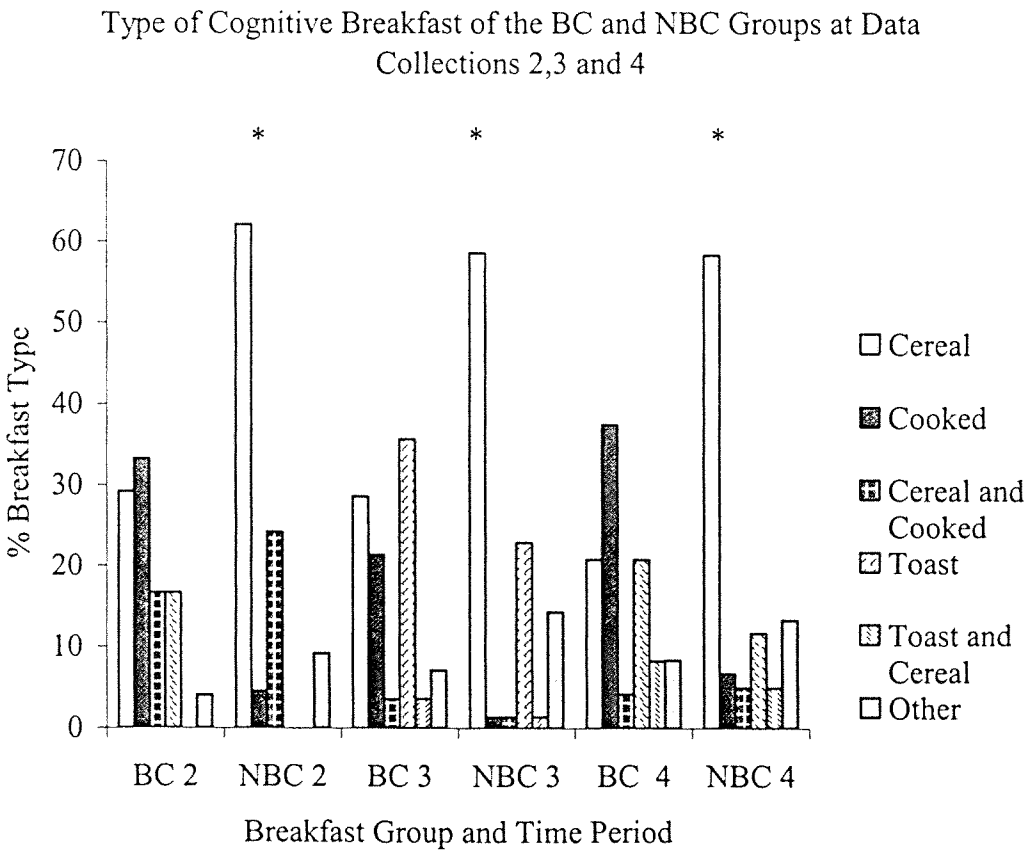


Figure: 4.2bType of Cognitive Breakfast of the BC and NBC Groups at Data Collections 2,3 and 4 (where * $p \leq 0.05$ and number of cereal eaters NBC 20 > BC 20)

At baseline there were no significant differences in the types of breakfast eaten by the BC and NBC group other than that there were no children eating both cereal and toast in the NBC . However after the commencement of the breakfast club there was a significantly higher percentage of cereal eaters ($p \leq 0.05$) in the NBC group as compared to the BC group which had a higher % of cooked breakfast eaters or children eating toast with margarine. This has an impact on the macronutrient and micronutrient composition of the different types of breakfast.

At all 3 data collection periods calorific intake was higher at the cognitive breakfast for the BC group (see figure 4.2c below)..

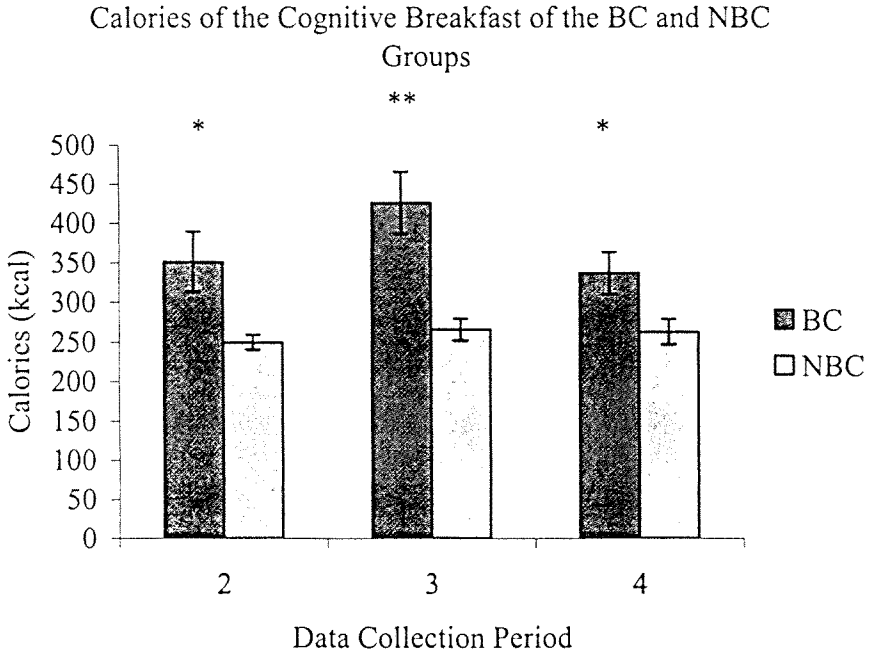


Figure: 4.2c Calories of the Cognitive Breakfast of the BC and NBC Group

where $^{+}$=0.05-0.06, $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

Whilst CHO *per se* was higher in the BC group the percentage energy of CHO was higher in the breakfasts of the NBC group as depicted in 4.2d. The percentage energy from starch was also higher in the NBC group at all time periods (see figure:4.2e). Glucose was available in greater amounts in the BC breakfast and significantly so at data collections 3 and 4 (see figure: 4.2f), whilst there was a trend for lactose and fructose to be higher in the

breakfasts of the NBC group at data collection 4 for the NBC group (see figures 4.2g and 4.2h).

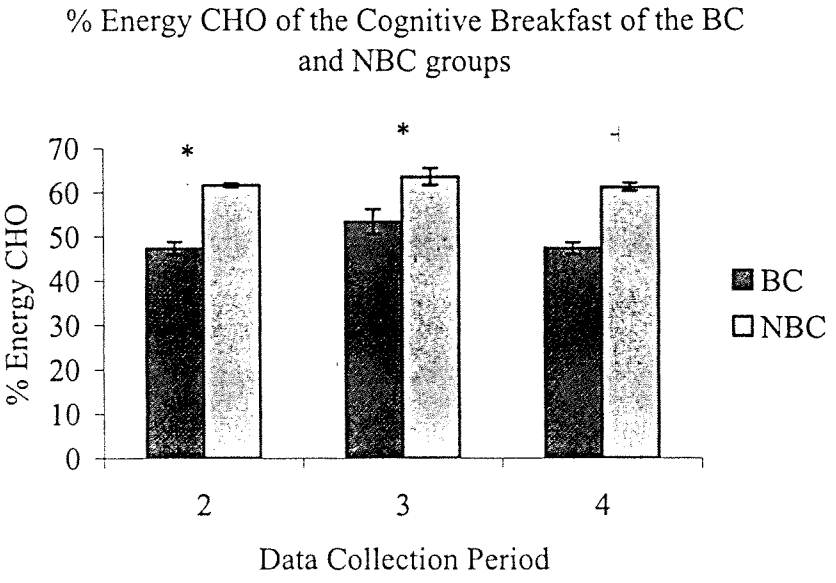


Figure 4.2d % Energy CHO of the Cognitive Breakfast of the BC and NBC groups where $^{+}$=0.05-0.06, $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

Figure: 4.2e % Energy Starch of the Cognitive Breakfast for the BC and NBC Groups

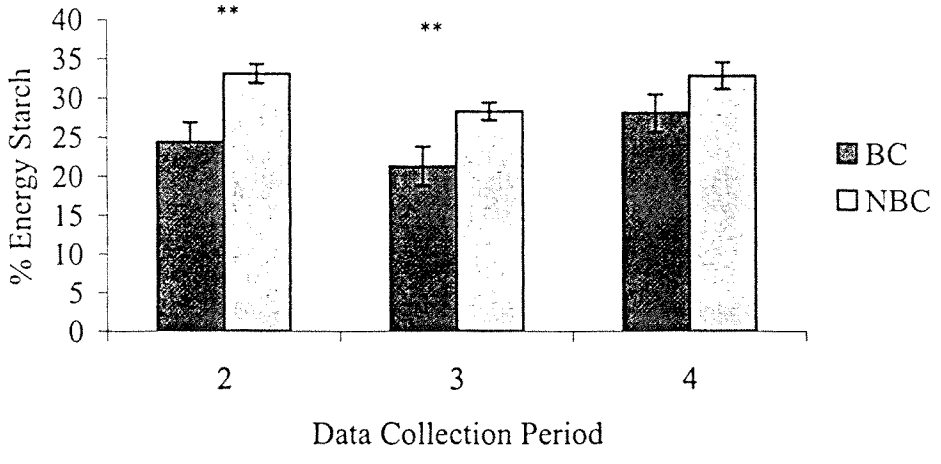


Figure: 4.2e % Energy Starch of the Cognitive Breakfast for the BC and NBC Groups where $^{+}$=0.05-0.06, $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

Figure: 4.2f Glucose of the Cognitive Breakfast for the BC and NBC Groups

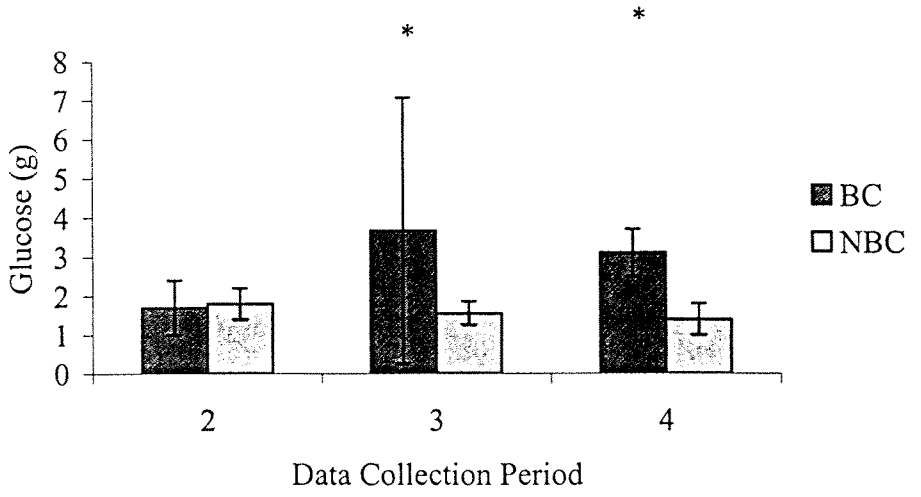


Figure: 4.2f Glucose of the Cognitive Breakfast for the BC and NBC Groups
where $^{+}$=0.05-0.06, $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

Lactose of the Cognitive Breakfast for the BC and NBC Groups

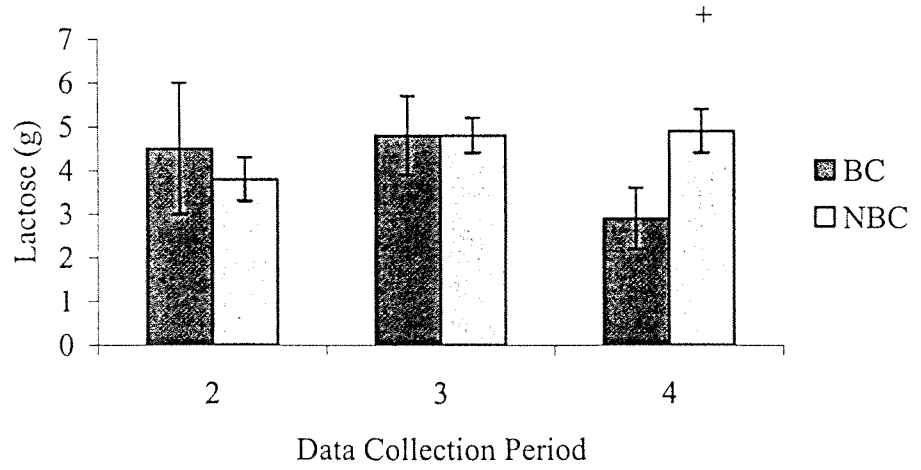


Figure: 4.2g Lactose of the Cognitive Breakfast for the BC and NBC
where $^{+}$=0.05-0.06, $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

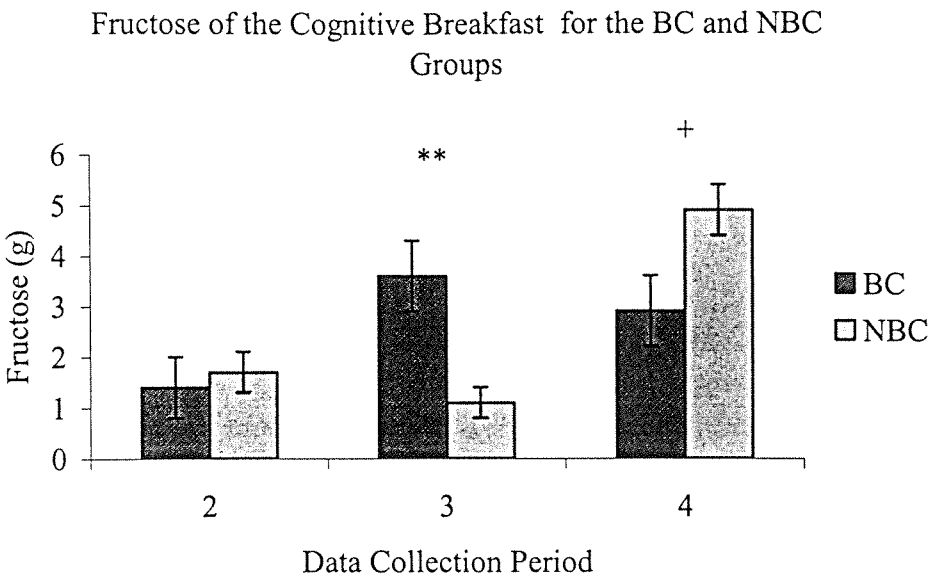


Figure: 4.2h Fructose of the Cognitive Breakfast for the BC and NBC Groups
where $^{+}$=0.05-0.06, $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

As illustrated in fig 4.2i-4.2l below there were differences in the amount of fat in the cognitive breakfast meals of the 2 groups. There was higher % energy from fat, PUFA and MUFA for the BC 20 group at all time periods.

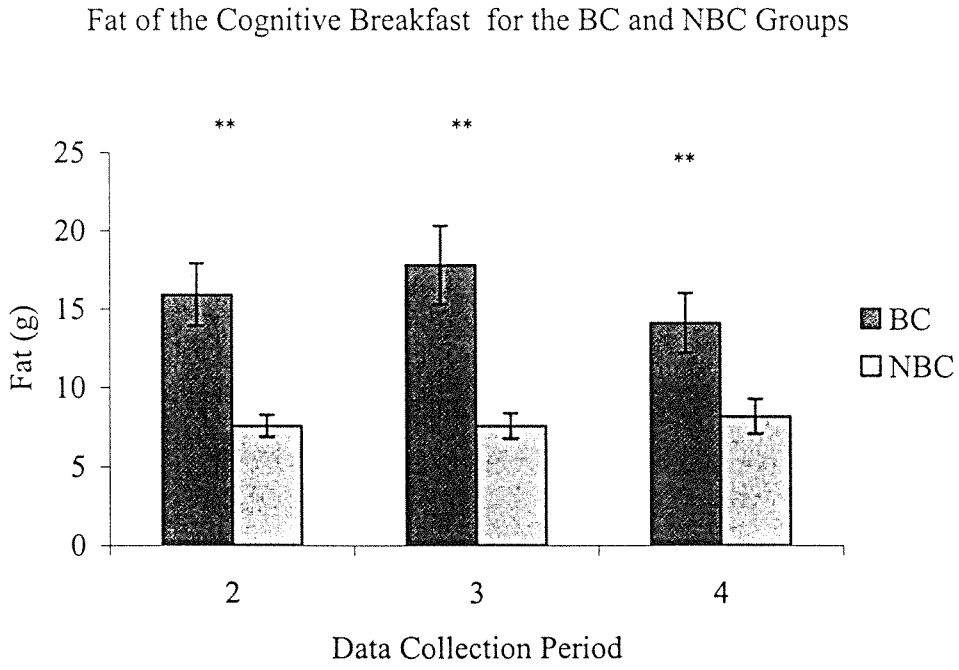


Figure: 4.2 i Fat of the Cognitive Breakfast for the BC and NBC Groups
where $^{+}$=0.05-0.06, $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

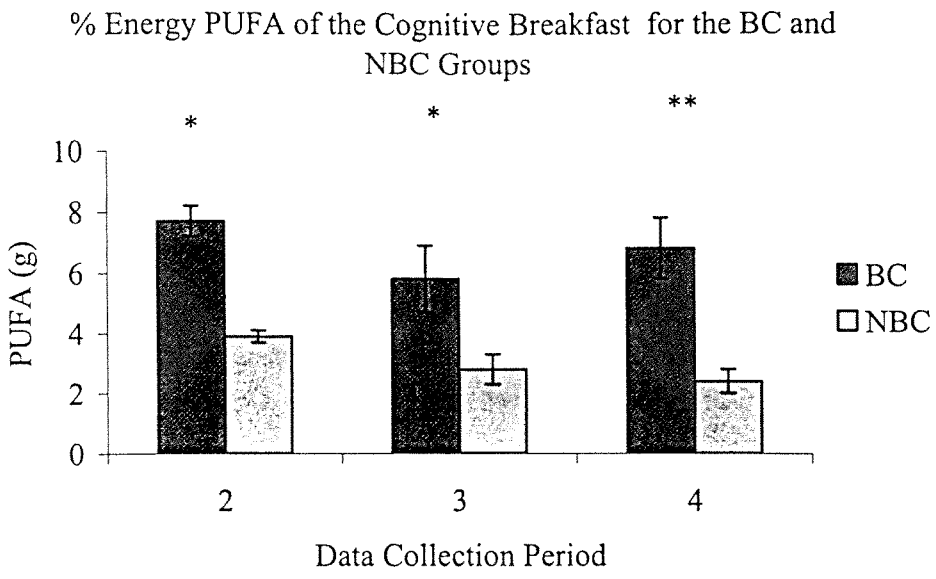


Figure: 4.2j % Energy PUFA of the Cognitive Breakfast for the BC and NBC Groups
where $^{+}$=0.05-0.06, $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

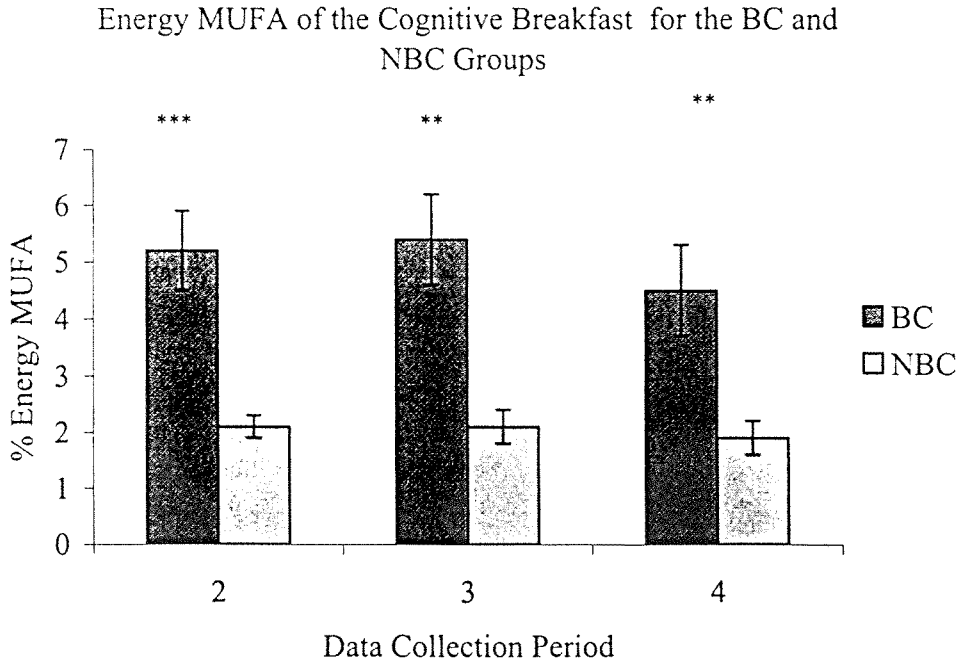


Figure: 4.2k % Energy MUFA of the Cognitive Breakfast for the BC and NBC Groups

where $^{+}$=0.05-0.06, $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

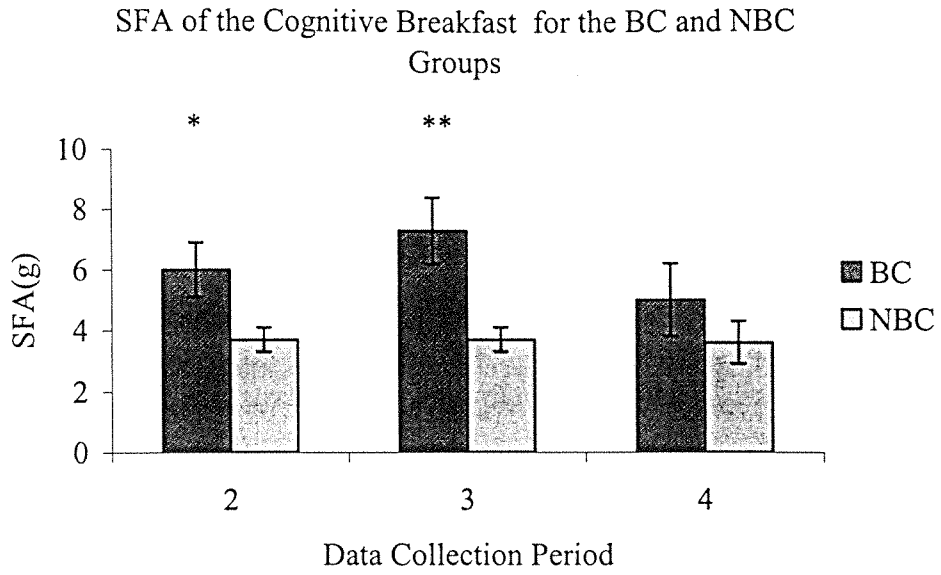


Figure: 4.2l SFA of the Cognitive Breakfast for the BC and NBC Groups

where $^{+}$=0.05-0.06, $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

4.2.3 Discussion

At baseline there were no significant differences in the types of breakfast eaten by the BC and NBC group other than that there were no children eating both cereal and toast in the NBC . However after the commencement of the breakfast club there was a significantly higher percentage of cereal eaters ($p \leq 0.05$) in the NBC group as compared to the BC group which had a higher % of cooked breakfast eaters or children eating toast with margarine. This has an impact on the macronutrient and micronutrient composition of the different types of breakfast. Since there was a significant difference in the % of children eating cereal breakfasts after the commencement of the breakfast club, there is a difference in % energy from CHO and fat between the groups.

As outlined in chapter 1 the specific content of food affects certain biochemical and hormonal functions in the body and brain, thus linking diet to behaviour and cognition. In fact rapid and specific changes in brain composition normally occur after each meal (Wurtman *et al.*, 1974). The mechanisms through which the macronutrients (CHO, protein and fat) can influence the neurochemistry or neural functioning of the brain are

beginning to be understood (Dye *et al.,* 2000). Whilst micronutrients (vitamins and minerals) have been shown to both impair and improve some aspects of cognitive performance the effects of these nutrients is implicated over a longer term (i.e. acute effects are unlikely) and is more likely to effect at risk populations, e.g. the elderly and the malnourished. Unlike other organs, the brain's energy requirements are met almost exclusively through aerobic glucose degradation (except during times of no carbohydrate intake and ketosis). It was traditionally assumed that through a homeostatic mechanism the brain is well supplied with glucose it's primary fuel and that its functions is not affected by normal fluctuations and variations in blood glucose (Booth, 1994). Recent evidence suggests however that raising blood glucose concentrations improves cognitive functioning (Hall *et al.,* 1989, Benton and Owens 1993, Owens *et al.,* 1994, Gold *et al.,* 1986, Messier 1987, Green *et al.*, 1997).

The differences in the nutritional profile of the breakfasts of the 2 breakfast groups at baseline and after the commencement of the breakfast club are presented in this summary and discussion. The difference in cognitive performance scores from baseline to data collections 2, 3 and 4 (see previous chapter 4.1) have also been discussed with reference to the differences in nutritional intake at the breakfast meal. Bearing in mind that this was a well nourished population where micronutrients are unlikely to have an effect on cognitive performance, the discussion has focused the effect of macronutrient composition (namely CHO and fat). The next chapter 4.3 will seek out correlations and possible relationships between the cognitive performance scores and nutrients in order to ascertain if any of the hypothesise put forward have any founding.

Since there was a significant difference in the % of children eating cereal breakfasts after the commencement of the breakfast club, there is a difference in % energy from CHO and fat between the groups.

Carbohydrate

At all 3 data collection periods calorific intake was higher at the cognitive breakfast for the BC group .The percentage energy from CHO was higher for the NBC group than the BC group at all time periods. The percentage energy from starch was also higher in the NBC group at all time periods. Glucose was available in greater amounts in the BC breakfast and significantly so at data collections 3 and 4, whilst there was a trend for lactose and fructose to be higher in the breakfasts of the NBC group at data collection 4 for the NBC group.

At data collections 3 and 4 the NBC group were achieving higher cognitive performance scores. From these dietary results its is possible to hypothesize that it is the % of energy from CHO for the breakfast meal that can affect cognitive performance. The fact that % energy starch is higher in the NBC breakfasts at data collection 2 and the cognitive performance of these children are greater could indicate that the gradual release of glucose from this source is important in maintaining optimum cognitive performance in the morning. Despite glucose levels being higher in the breakfasts of the BC group cognitive performance scores are lower than the NBC group. Testing of the children took place 20-1.5hrs after breakfast was eaten and it is likely that this glucose eaten first thing in the morning will have been rapidly used up even before testing commenced. The breakdown of starch in the breakfast meal will supply the brain with glucose.

Glucose is the main source of the acetyl groups used in the formation of acetyl CoA) (Tucek, 1983) by oxidation of pyruvate dehydrogenase (Cooper *et al.*, 1986) and the association between acetylcholine-mediated neurotransmission and memory is well accepted (Bartus *et al.*, 1982, Durkin *et al.*, 1992, Kopelman, 1986). In addition to its role in cholinergic biochemistry glucose also contributes to the production of energy for brain neurons (e.g. ATP) (Tyce *et al.*, 1983). Carbohydrate provides the most rapidly available source of glucose the brain's primary metabolic fuel (Dye *et al.*, 2000). A breakfast higher in percentage energy from CHO might benefit short-term memory by supplying the brain with a readily available and steady supply of this fuel. Therefore the %

of energy of CHO, starch or sugars of the breakfast meal may influence the supply of glucose and hence acetylcholine and ATP to the brain, thereby affecting performance. There is a wealth of evidence documenting the beneficial effects of a glucose drink on cognitive performance in healthy young adults (e.g. Benton *et al.,* 1987, 1989, 1990, 1995, 1999 Conners *et al.,* 1984, Foster *et al.,* 1998) as described in chapter 1. Research into breakfast at school and cognition have mainly focused the non-breakfasted versus breakfasted condition in undernourished or malnourished children where a positive impact from eating breakfast would be expected.

There are relatively few studies that have looked at different breakfast types and cognitive performance specifically. Smith looked at the effect of a cooked breakfast versus cereal and toast in a group of students (Smith *et al.* 1994). Whilst breakfast had no effect on the performance of sustained attention tasks, there was an improvement in mood for students eating a cooked breakfast. In contrast Lloyd showed that significant improvements were found in his group of students when they consumed a low fat, high-CHO breakfast as opposed to a high fat-low CHO meal (Lloyd *et al.,* 1996). The specific effects of a cereal breakfast on child performance have been researched recently and have shown that declines in attention and memory are significantly reduced by the consumption of cereal in the morning as compared to the no breakfast condition or a glucose drink (Wesnes *et al.,* 2003). The researchers concluded that a cereal breakfast had a positive effect on the cognitive function of schoolchildren, particularly towards the end of the morning and that a typical breakfast of cereal rich in complex CHO can help maintain mental performance over the morning. Benton *et al.,* 2003 found that a breakfast high in slowly rather than rapidly available glucose benefited memory later in the morning. Whilst it has been beyond the parameters of the thesis to look at glycaemic index (GI) or glycaemic load (GL) this is a factor that should also be taking into consideration when interpreting the results.

Fat

There was higher % energy from fat, PUFA and MUFA for the BC 20 group at all time periods. This was due to the higher % of cooked breakfast and toast with margarine being consumed by the BC 20 group. Little decisive research has been carried out regarding the effect of diet fat on performance (Bellisle *et al.,* 1998). On balance, high-fat meals appear to increase subsequent fatigue and reduced reported alertness, but with little effect on cognitive performance, relative to high-CHO-low-fat meals. Wells and Read (1996) found that subjects felt less vigorous and more dreamy and feeble after a low CHO/high fat meal. It was suggested that the mood changed reflected the fat rather than the CHO since lipid infusion into the duodenum was found to reduce alertness (Wells *et al.,* 1995). In contrast Holt (1999) found that participants who consumed a high fibre cereal, were more alert than after the consumption of a fat-rich meal. The effect of fat on fatigue would not be a consideration in the present research since cognitive testing took place 30mins-1.5 hrs after breakfast at which point duodenal fat would not be able to produce a change in systemic nutritional state. Nevertheless the changes in fat and % energy fat will affect the % energy of CHO, since intakes % there were no differences in % energy protein from the breakfasts of both groups and % energy from protein remained relatively stable throughout the study.

4.3 Nutrient and Cognitive Performance Correlations

The relationship between nutrient intake at breakfast and the digit span, coding and arithmetic subsets of the WISC-III^{uk} were explored. Nutrient intake was correlated to cognitive function scores using Pearson correlations. The specific content of food affects certain biochemical and hormonal functions in the body and brain, thus linking diet to behaviour and cognition.

The relationship between nutrient intake and cognitive function is dependent on many factors. The nutritional status of the individual is an important consideration and (as discussed in chapter 1) studies on malnourished populations have shown that macronutrients and micronutrients can effect cognition in these individuals to different extents. We have presumed however that the population looked at in this study were adequately nourished. The effect of specific nutrients on the cognitive measures were dependent on the time between the consumption of breakfast and the time of testing. Cognitive function testing was carried out between 15 mins to 1hr 30 mins after the consumption of breakfast. The effect of nutrient load will therefore have been affected by the composition of the specific breakfast and the time required for nutrient intake to affect the biochemical profile of the blood and thereafter the brain.

The emphasis of this research is therefore on the acute effects of breakfast on cognition. For this reason sugars (glucose, sucrose, maltose and lactose), carbohydrate, protein and fat and percentage energy of these nutrients are of particular interest and are shown below. Correlations between some micronutrients and cognitive function are also presented, although the interpretation of these findings were addressed with caution since the effect of micronutrients namely the B-complex vitamins and folate and anti-oxidants on cognition are likely to have an effect over a sustained period of time.

In the tables below total population refers to both the BC (breakfast club) group and the NBC (non breakfast club) group. Correlations between nutrients and cognitive function scores were explored for the total population and the BC and NBC group separately.

4.3.1 Positive Correlations Between Nutrient Intake and Cognitive Performance Scores

Tables 4.3i , 4.3 k and 4.3m show that there was an association between carbohydrate and cognitive function scores. Tables 4.3j, 4.3m and 4.3o. show the relationship between micronutrients and cognitive function scores.

Table: 4.3a Macronutrient and Cognitive Performance Correlations For the Total Population

Nutrient	Digit	Coding	Arithmetic
Glucose	Data 3		
Fructose	Data 3		
% Energy Sugars		Data 3	Data 3
% Energy Starch		Data 4	
% Energy CHO		Data 3, Data 4	
% RNI CHO			

Table: 4.3b Micronutrient and Cognitive Performance Correlations For the Total Population

Nutrient	Digit	Coding	Arithmetic
Vitamin B2 (mg)		Data 4	
Vitamin B6 (mg)		Data 4	
Folate (ug)		Data 4	
Vitamin D (ug)	Baseline, Data 2, Data 3		

Table: 4.3c Macronutrient and Cognitive Performance Correlations For the BC Group

Nutrient	Digit	Coding	Arithmetic
% Energy Starch		Data 4	
% Energy CHO		Data 3, Data 4	

Table: 4.3d Micronutrient and Cognitive Performance Correlations For the Total Population

Nutrient	Digit	Coding	Arithmetic
Vitamin B2 (mg)		Data 4	
Vitamin B6 (mg)		Data 4	
Folate (ug)		Data 4	
% RNI Vitamin D (ug)			Data 3

Table: 4.3e Macronutrient and Cognitive Performance Correlations For the NBC Group

Nutrient	Digit	Coding	Arithmetic
CHO		Data 4	
% Energy Sugars		Data 3	
% Energy Starch		Data 4	
% Energy CHO		Data 4	

Table: 4.3f Micronutrient and Cognitive Performance Correlations For the NBC

Nutrient	Digit	Coding	Arithmetic
Vitamin A	Data 3		
Vitamin B2 (mg)		Data 4	
Vitamin B6 (mg)		Data 4	
Folate (ug)			
Nicotinic acid		Data 4	

4.3.2 Discussion

As discussed in the literature review there has been a plethora of research to show the improvement of cognitive performance after administration of glucose (Benton *et al.*, 1987, 1989, 1990, 1995, 1999, Conners *et al.*, 1984, Foster *et al.*, 1998) and recent evidence by Wesnes revealed that blood glucose levels following cereal consumption lead to improved memory as compared to other types of breakfast (Wednes, 2003). Recent evidence suggests however that raising blood glucose concentrations improves cognitive functioning (Hall *et al.*, 1989, Benton and Owens 1993, Owens *et al.*, 1994, Gold *et al.*, 1986, Messier 1987, Green *et al.*, 1997) Since CHO foods are readily digested and metabolised to produce glucose the brain's preferred metabolic fuel, this could provide an explanation for the positive association between cognitive performance scores and carbohydrate. Glucose is a precursor for acetylcholine synthesis and is used in the generation of ATP. The mechanisms by which glucose may affect cognition will be discussed further in the final discussions.

The possible relationship between micronutrient intake and cognitive performance has not discussed so far because micronutrient intakes are only likely to affect malnourished and undernourished populations over a period of time. The children in this study were well nourished.

It is a common finding that psychological function decreases with age, and there is a large body of evidence which indicates that vitamin status is an important mediator in the maintenance of efficient cognitive processing (Dye *et al.,* 2002. In particular a number of vitamins have functional utility in the maintenance of the central and peripheral nervous system. Deficiencies in the B-vitamin group (thiamin, B_2, B_6, B_{12} and folate) have been linked with conditions such as irritability, depression, peripheral neuropathy and myelin degeneration. (Rosenberg and Miller, 1992). One possible route whereby deficiencies in these vitamins may affect cognition relates to their role in the metabolism of the S amino acid homocysteine. Plasma levels of homocysteine have been inversely correlated to levels of B12 (Koehler *et al.,* 1996; Lussier-Cacan *et al.,* 1996), vitamin B6 and folate (Selhub *et al.,* 1993). Importantly, supplementation with a range of B-complex vitamins reduces serum homocysteine levels in both the elderly (Koehler *et al.,* 1996) and younger (Woodside *et al.,* 1998) populations. It has been found that Alzhiemer's patients exhibit significantly higher levels of homocysteine (McCaddon *et al.,* 1998) and these levels are also predictive of neuropsychological status in individuals suffering from other forms of dementia (Lehman *et al.*, 1999). A recent study by Bryan *et al.* (2002) revealed that supplementation of the B-vitamins in a group of 211 health middle aged women had a positive effect on memory performance. Dietary intake status was associated with speed of processing, recall, recognition and verbal ability. As yet there have no such studies in children but the positive correlations between cognitive performance in the B-vitamins shown in Figure 7.3m below require further investigation. Cereal is fortified with B-vitamins and so this correlation could reflect the high CHO consumption at breakfast relation that an actual association between cognitive performance and these vitamins.

5.1 Child Behaviour

Child behaviour was measured using the Achenbach Teacher Report Form (see chapter 2). The report form was completed by the form teacher at baseline and at data collection 4. As described in the methodology the report form was shortened for this study due to time restraints. The results however can still be divided into the original domains for scoring.

5.1.1 Baseline – October/November 2000

Two schools opened up breakfast clubs at the end of November 2000 and these schools have been classed as the breakfast club schools (BC SCH) for the following analysis. The two schools which did not open breakfast clubs have been classed at non breakfast club schools (NBC SCH). At baseline the breakfast clubs had not started. In order to assess the possible differences in child behaviour between the two types of schools all children who attended a breakfast club school have been placed in the BC SCH (n=69) (regardless of whether they went onto attend the club at any data collection point) and those who did not attend a breakfast club school have been placed in the NBC SCH (n=43).

Child Behaviour at Baseline of the Breakfast Club Schools (BC SCH)and Non Breakfast Club Schools (NBC SCH).

The following domains were measured by the Achenbach teacher report form :

academic performance, working hard, behaving appropriately, learning, happiness

adaptive functioning, withdrawn behaviour, somatic complaints, somatic score, anxiousness/depression, internalising behaviour, social problems, thought problems, attention problems, inattention, hyperactivity-impulsitivity, delinquent behaviour, aggressive behaviour, externalising behaviour and other probs.

There were no differences between the BC SCH and NBC SCH in any of these areas.

Child Behaviour at Baseline of the Breakfast Club Children (BC) and Non Breakfast Club Children (NBC).

The baseline data was re-analysed for children who actually attended the breakfast club (BC) at data collection 4 (n=32) and those who did not attend the breakfast club (NBC) at data collection 4 (n=64).

Again there were no differences between the groups of children for any domains measured.

5.1.2 Data Collection 4 – May- June 2001

At data collection 4 Teacher Report Forms were unmarked by one of the breakfast club schools. Therefore it has not been possible to analyse the data for this data collection period.

6.1 The Breakfast Meal

There were 20 subjects in the study who remained in the breakfast club throughout data collections 2, 3 and 4. These subjects have been designated the Breakfast Club 20 group (BC20). This group have been matched by age, gender, height, weight and BMI to 20 subjects who had breakfast at home throughout data collections 2,3 and 4 and have been designated the Non Breakfast Club 20 group (NBC20). Matching the groups in this way makes comparisons between them robust. It is also possible to compare data collection period with each other. The results below represent mean values of nutrient intake from breakfast over the 3–days of data collection at baseline and each of the 3 subsequent data collection periods.

The purpose of this chapter is to:

examine the differences between breakfast intake of the BC 20 and NBC 20 group at baseline and data collection 2,3 and 4 and to compare these with RNIs.

Subject Numbers and Characteristics

Subject characteristics for this part of the results have been described on the previously in chapter 2.4. However due to children missing days off school and missing data there has been a fluctuation in the number of children at each data collection period. This has been illustrated in table 6.1a below.

Table 6.1a Number of Subjects in the BC 20 and NBC 20 Group for the Breakfast Meal Nutrient Analysis

	Baseline	Data Collection 2	Data Collection 3	Data Collection 4
BC 20	20	15	18	16
NBC 20	18	17	19	19

Table: 6.2b Subject Characteristics of the BC 20 and NBC 20 Group for the Breakfast Meal Nutrient Analysis

	BC 20	NBC 20
Baseline		
Age	9.4(± 0.2)	9.2(± 0.23)
Gender	10F:10M	10F:8M
Data Collection 2		
Age	9.6(± 0.3)	9.4(± 0.4)
Gender	7F:8M	10F:7M
Data Collection 3		
Age	9.8(± 0.3)	9.6(± 0.2)
Gender	9F:9M	9F:10M
Data Collection 4		
Age	10.0(± 0.3)	9.8(± 0.2)
Gender	8F:8M	10F:9M

6.1.1 Breakfast at Baseline

Types of Breakfast Eaten at Baseline of theBC20 and NBC20 Groups

Breakfast at baseline refers to the breakfast eaten by the BC20 and NBC20 group before the commencement of the breakfast club. Therefore at this period at the subjects were consuming breakfast at home . At this data collection point 55% and 50% of the BC20 and NBC20 group respectively were eating cereal only for breakfast. Cooked breakfasts were consumed by 5.0% of the BC20 group and 5.6% of the NBC20 group. A quarter of the BC20 group were consuming a cooked breakfast as compared to 16.7% of the NBC20 group. Both toast and cereal was consumed by 5.0% of the BC20 group and 5.6% of the NBC20 group. A small percentage of both groups were consuming combinations of a cooked, toast and cereal breakfast with sweets or crisps. At this data collection point there were no differences between the groups for children eating cereal only during the 3 days of measurement, or children eating a cooked meal only.

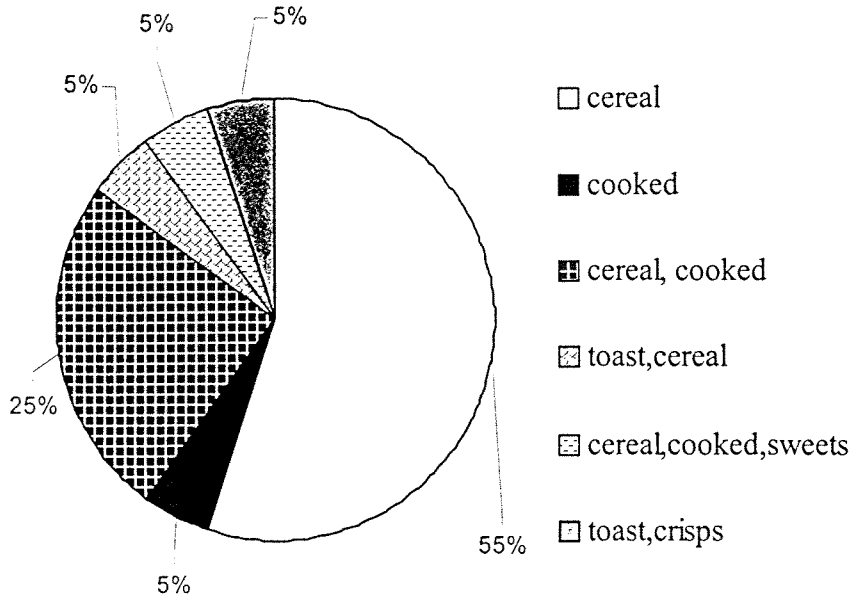


Figure 6.1a : Breakfast Type of the Breakfast Club 20 Group (BC20) at baseline

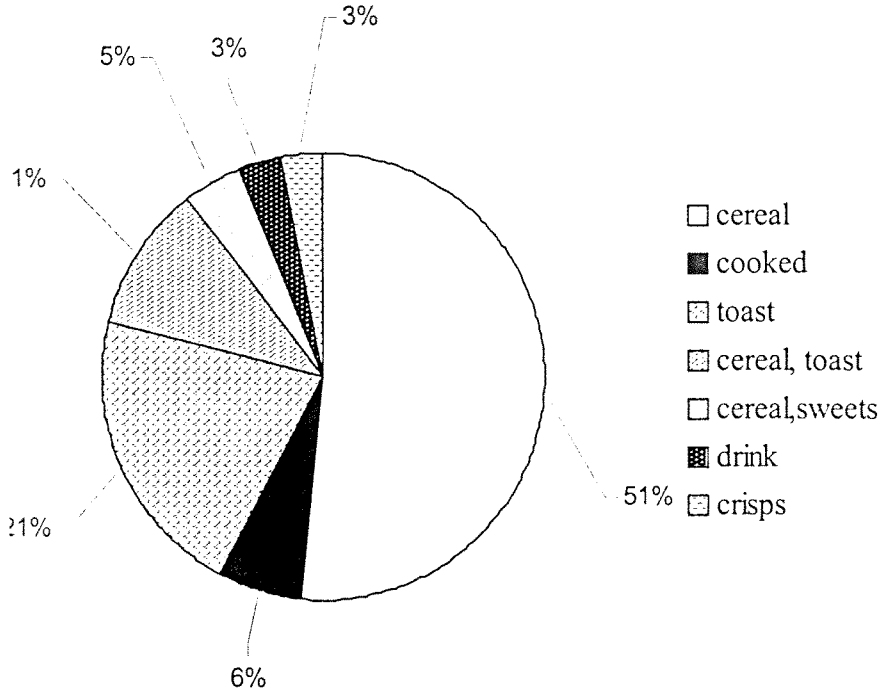


Figure 6.1b : Breakfast Type of the Non-Breakfast Club 20 (NBC20) at Baseline

Macronutrients from the Breakfast at Baseline for the BC 20 and NBC 20 Group (NBC20) at baseline

The mean calorie intake over the 3-days of dietary assessment was 254.8±22.4 kcals in the BC20 group and 242.8± 20.8 kcals in the NBC 20 group. This provided 10.1± 2.3% and 6.9± 0.7% of the RNI for calories for the 2 groups. Percentage energy from fat was 5%

higher in the BC 20 group at 24.9± 3.4% as compared to 19.4± 2.9% in the NBC20 group. There was no difference in the types of fat between the 2 groups. CHO provided 63.1± 4.4% of the energy for the NBC 20 group and 64.0% of the energy for the BC 20 group. The percentage of energy from protein at breakfast was equal in both groups at 11.9± 1.0% and 11.0± 0.8%.

Micronutrient Intake from the Breakfast at Baseline Breakfast for the BC 20 and NBC 20 Group

Breakfast provided 127.6mg(±13.5) and 138.0mg(±14.4) of calcium for the BC20 and NBC20 group respectively. This provided over 20% of the RNI for calcium. There were no differences in the amount of iron in the 2 breakfast groups and the breakfast meal also provided over 20% of the RNI for this micronutrient. As indicated in table 6.1d below the BC 20 group were receiving a higher % of the RNI for vitamin C at 58.2±20.1% whereas only 2.9±1.5% of the RNI for this vitamin was provided by the NBC 20 group ($p \leq 0.05$). There were no differences in the amount of B vitamins between the 2 groups. Breakfast provided over 40% of the RNI for vitamin B2, nicotinic acid and vitamin B12. The BC 20 breakfast provided 36.7±5.8% of the RNI for vitamin B1 and 43.1±5.5% of vitamin B1 was available from the NBC 20 breakfast. Approximately 30% of the RNI for vitamin B6 was provided by both breakfasts. For both groups over 35% of the RNI for folate was consumed in the breakfast meal.

6.1.2 Differences in Nutrient Intake from the Breakfast Meal of the BC20 and NBC20 Groups

Macronutrient Differences Between The Breakfast Meals Of the BC 20 and NBC 20 Groups

As illustrated in the figure 6.1c below calorie intake from breakfast meal was greater for the BC 20 group at all 4 data collection points and the difference in calorific intake between the groups was significant at data collections 2 and 3 ($p \leq 0.05$).

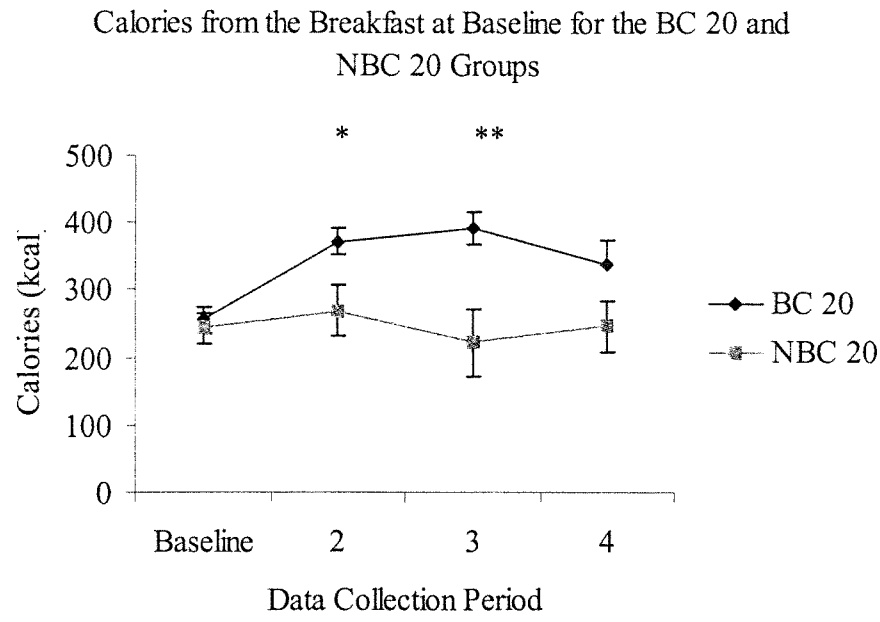


Figure: 6.1c Calories from the Breakfast Meal of BC 20 and NBC 20 Groups
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

Protein intake as illustrated in the figure 6.1d below was also greater at all data collections points for the BC 20 group and the difference in protein intakes between the BC 20 and NBC 20 groups was significant at data collections 3 and 4.

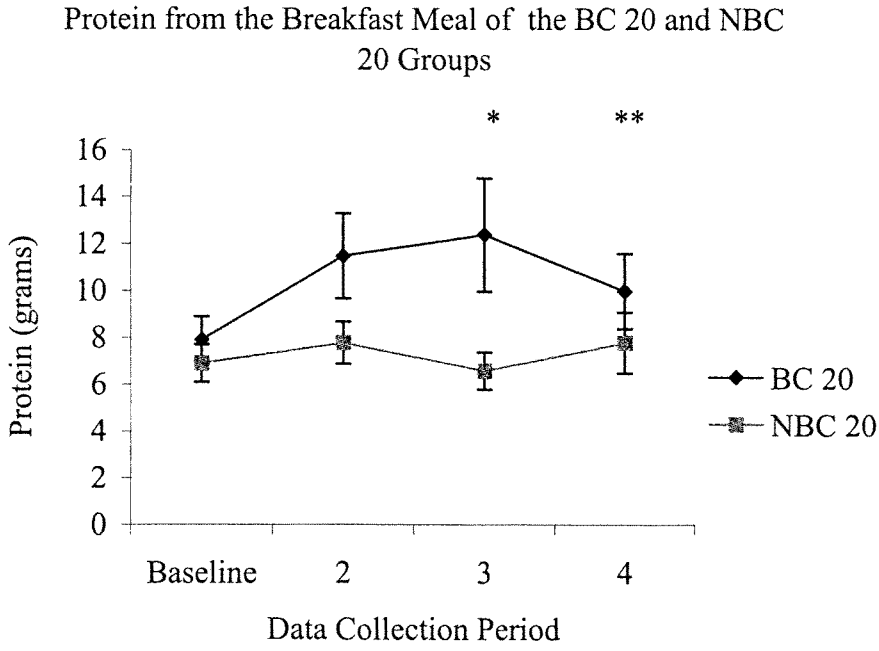


Fig: 6.1d Protein from the Breakfast Meal of the BC 20 and NBC 20 Groups
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

Fat consumption from the breakfast meal was greater in the BC 20 group at for the entire study. Figure 6.1e demonstrates that fat intake was significantly greater at data collections 2 and 3.

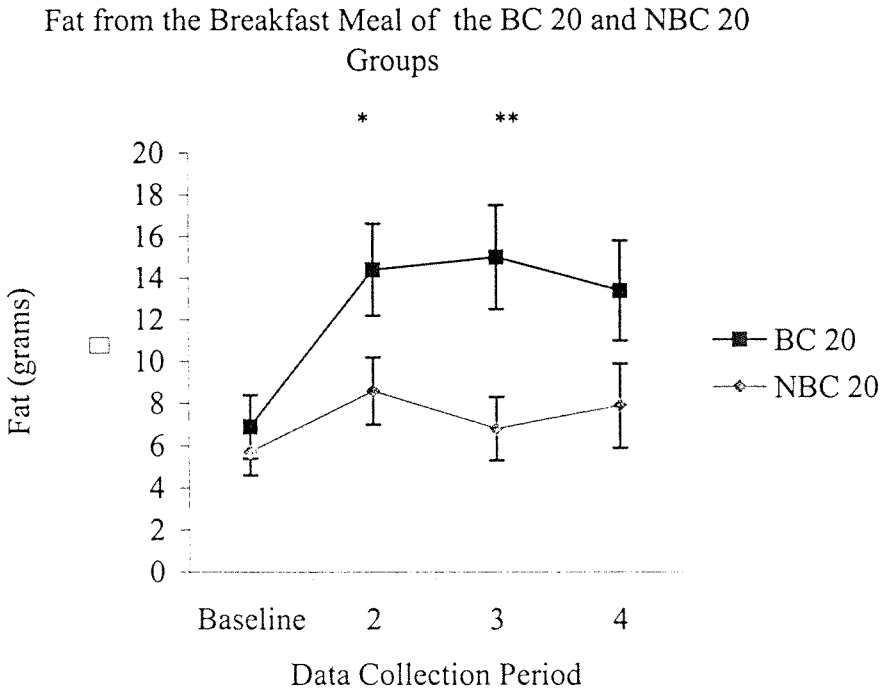


Figure 6.1e : Fat from the Breakfast Meal of the BC 20 and NBC 20 Groups
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

The difference in fat intake was due to a difference in PUFA and MUFA intakes. As illustrated in figures 6.1f and 6.1g there were differences between the groups in the amount of PUFA (grams) and % energy from PUFA for all data collection 2,3 and 4 after the commencement of the breakfast club. This fat was higher in the breakfasts consumed by the BC 20 group. There was also a difference in the % RNI of PUFA at data collections 3 and 4 . The amount of MUFA (grams) was also greater in the breakfasts consumed by the BC 20 group at all data collections 2, 3 and 4 as illustrated in 6.1h and 6.2i. The percentage of energy of MUFA from the breakfast meal was also greater for the BC 20 groups. As illustrated in 6.1 j at data collection 4 % RNI SAT at the breakfast meal was significantly higher for the BC 20 group.

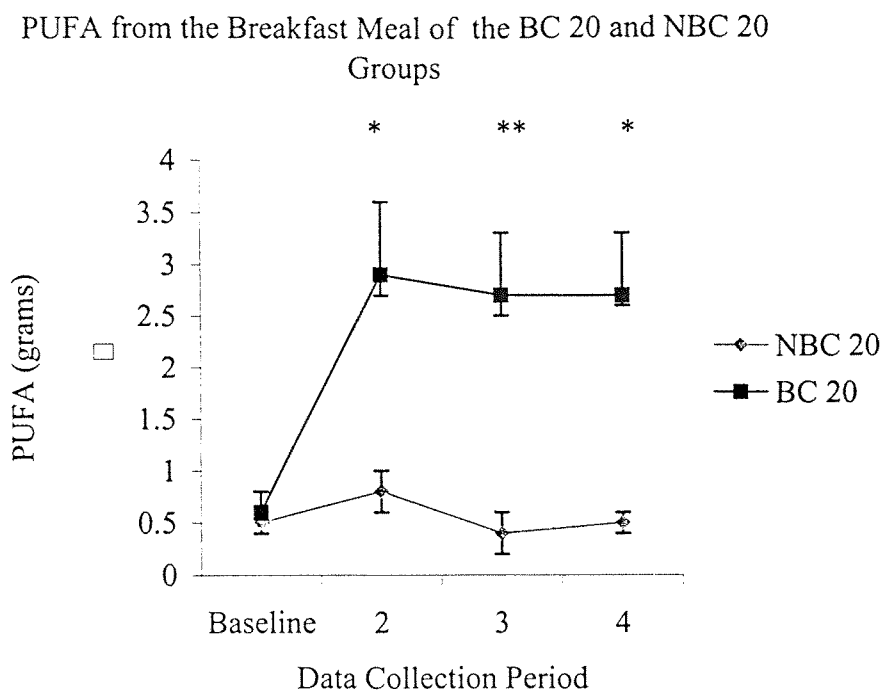


Figure 6.1f : PUFA from the Breakfast Meal of the BC 20 and NBC 20 Groups
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

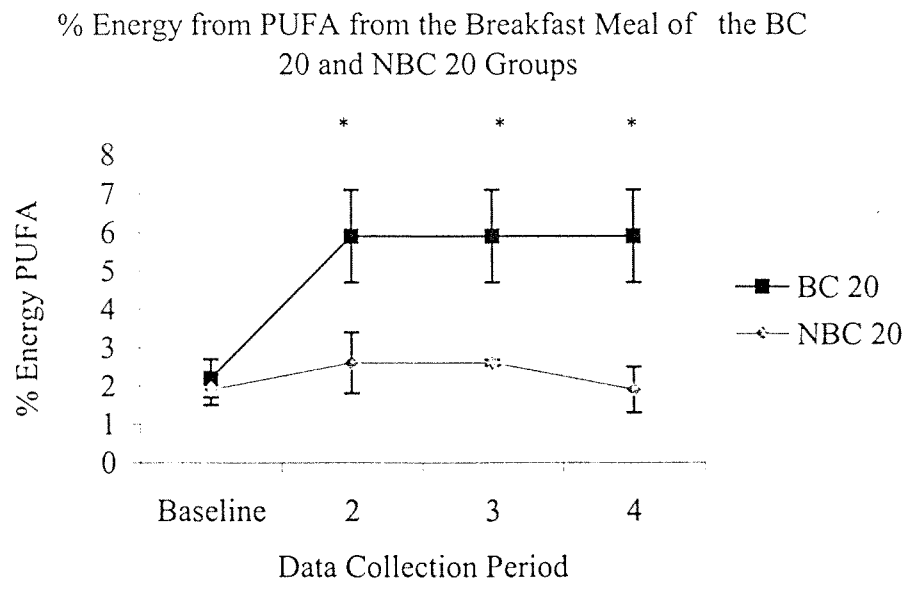


Figure 6.1g % Energy from PUFA from the Breakfast Meal of the BC 20 and NBC 20 Groups
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

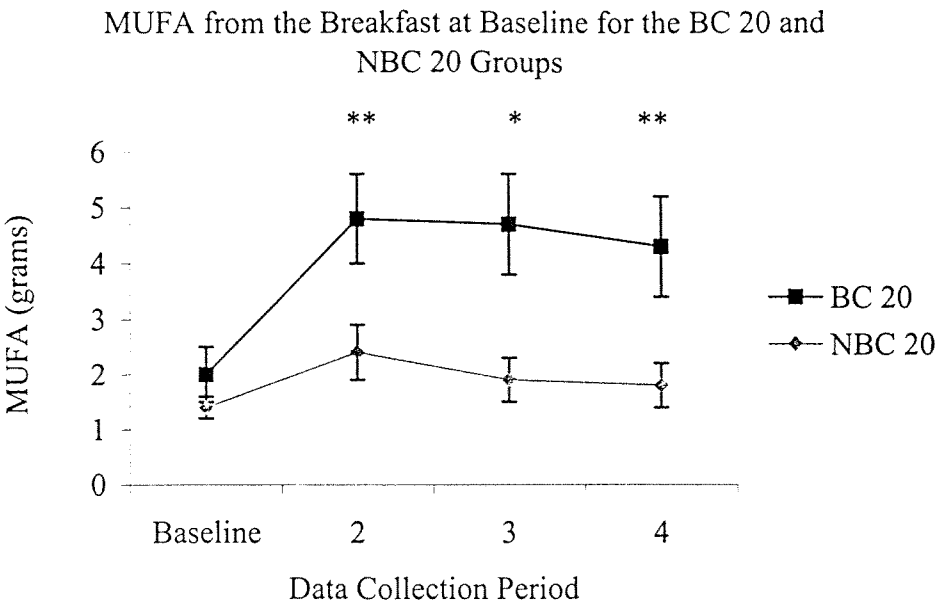


Figure 6.1h : MUFA from the Breakfast at Baseline for the BC 20 and NBC 20 Groups
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

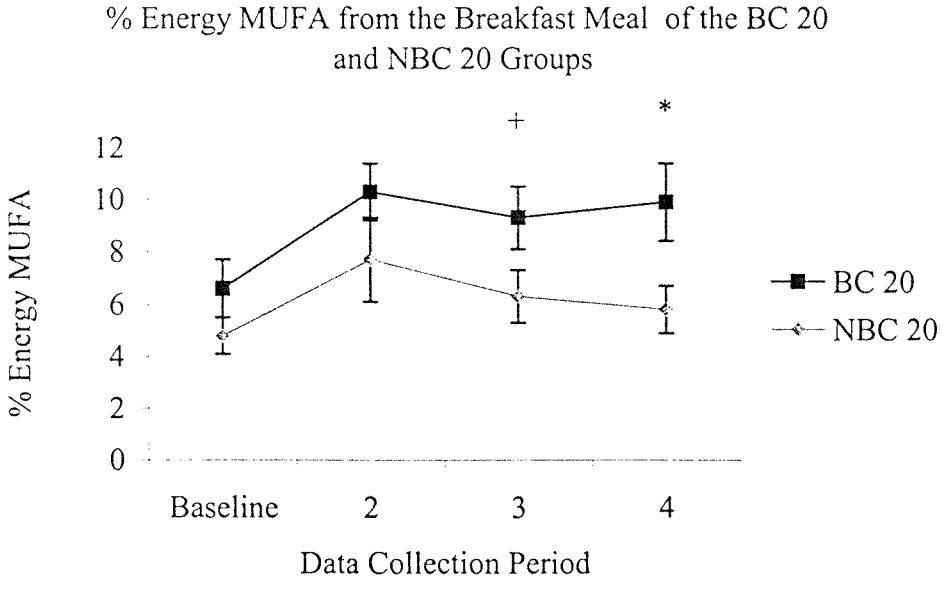


Figure 6.1i : % Energy MUFA from the Breakfast Meal of the BC 20 and NBC 20 Groups
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

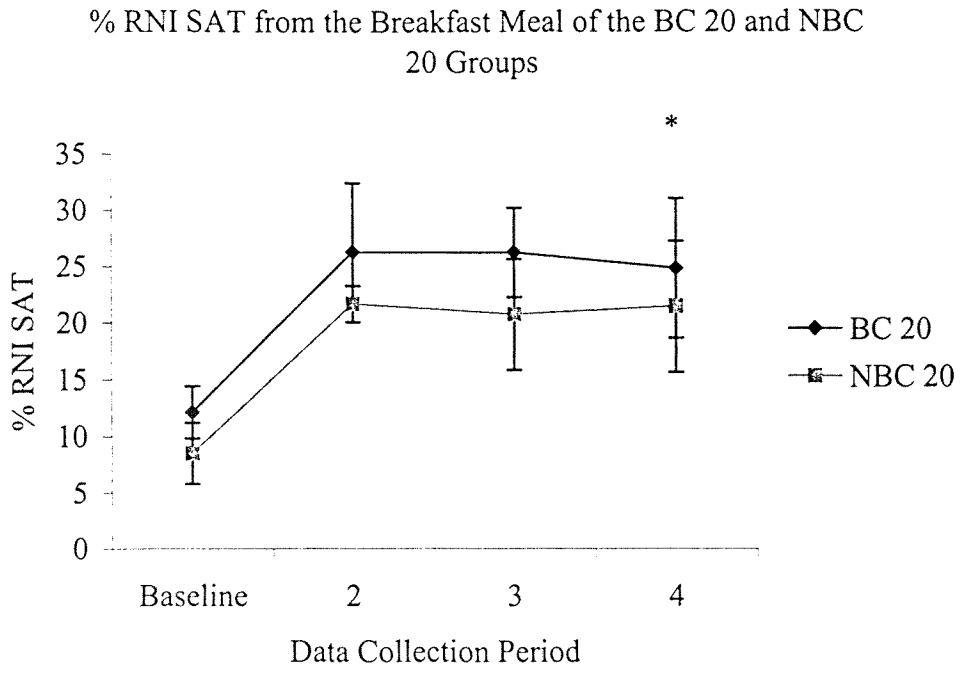


Figure 6.1j : % RNI SAT from the Breakfast Meal of the BC 20 and NBC 20 Groups
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

CHO intake was greater for the BC 20 group at data collections 2,3 and 4 after the commencement of the breakfast club (see figure 6.1k). The intake of CHO was significantly greater for the BC 20 group at period 3 and % RNI CHO from the breakfast meals was also significantly greater at this data collection point as illustrated in figure 6.1u. There was more starch in the BC 20 breakfast also at all data collection periods as shown in figure 6.1l.

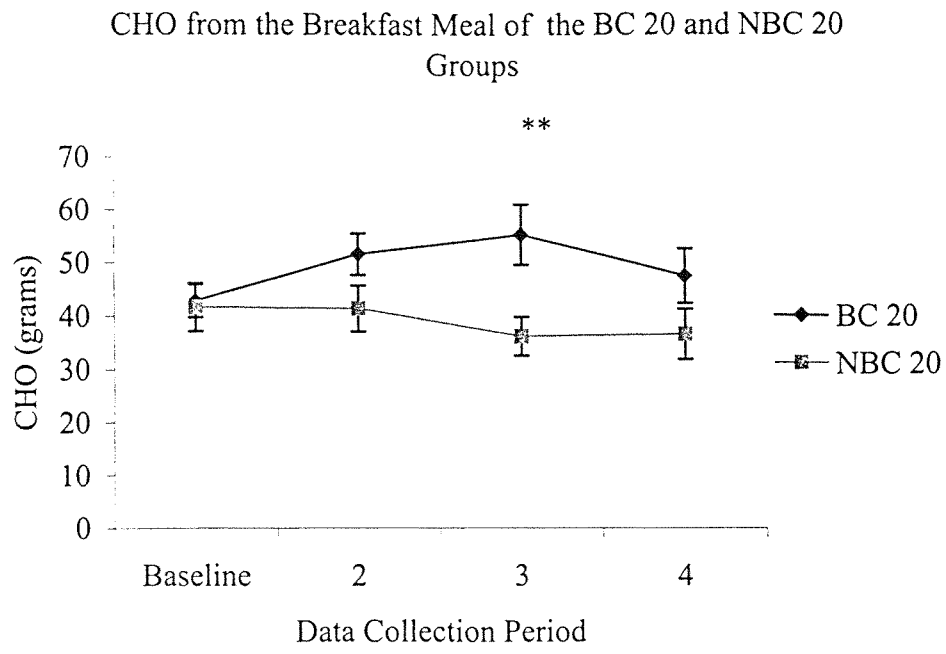


Figure: 6.1k CHO from the Breakfast Meal of the BC 20 and NBC 20 Groups where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

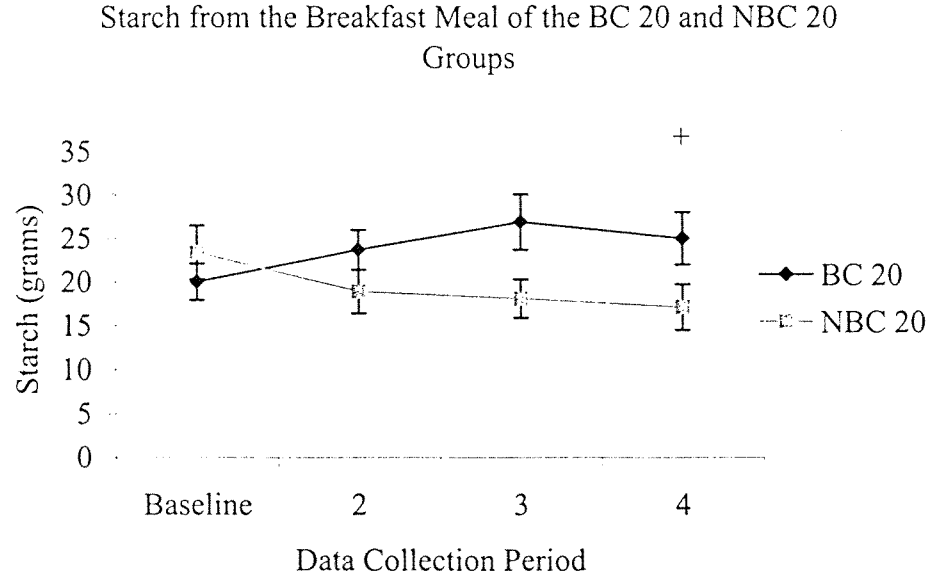


Figure: 6.1l Starch from the Breakfast Meal of the BC 20 and NBC 20 Groups where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

Summary of Micronutrient Differences Between The Breakfast Meals Of the BC 20 and NBC 20 Groups

Calcium intake at breakfast was higher in the BC 20 group than the NBC 20 group at data collections 2 ,3 and 4 after the opening of the breakfast club. As illustrated in figures 6.1m and 6.1n the amount of Ca (mg) and the % RNI Ca was significantly greater for the BC 20 group at data collection 3.

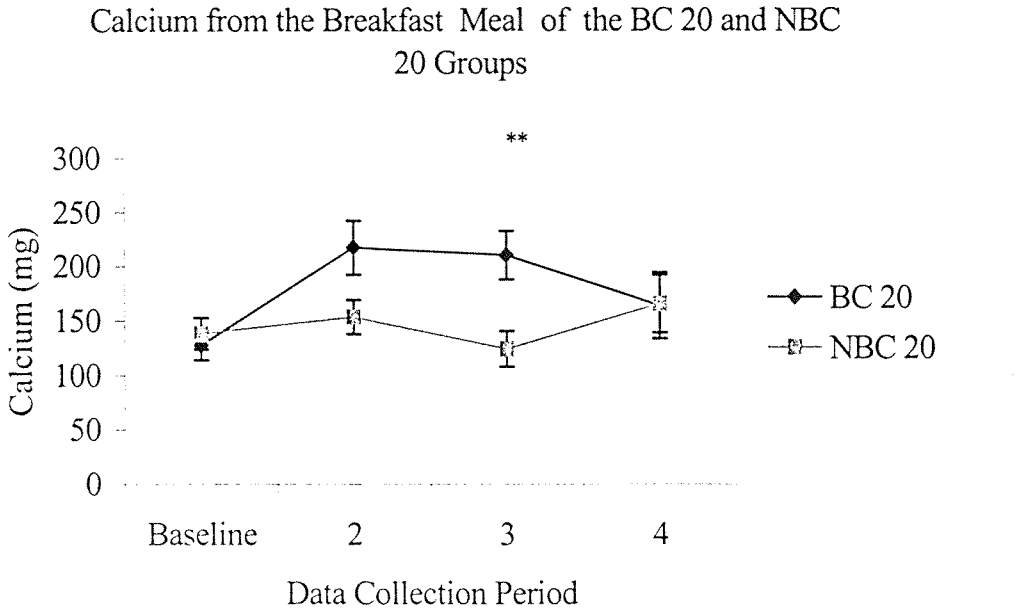


Figure 6.1m Calcium from the Breakfast Meal of the BC 20 and NBC 20 Groups where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

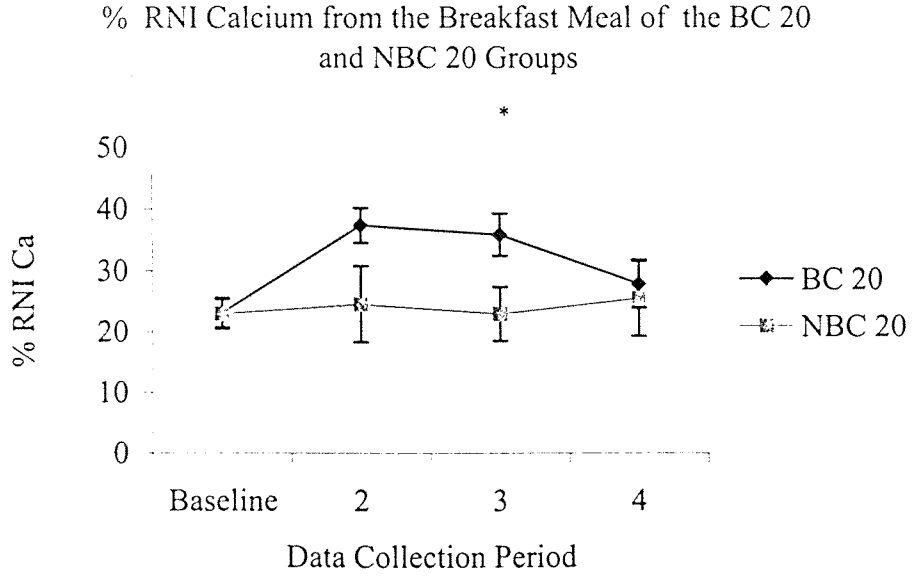


Figure 6.1n : % RNI Calcium from the Breakfast Meal of the BC 20 and NBC 20 Groups where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.00$

Vitamin C intakes were greater for the BC 20 group at all data collection periods including the baseline measurements before the start of the breakfast club. The intakes of vit C *per se* and the % RNI vit C in the breakfast meal was significantly higher or close to significance at the baseline collection and collection 2 and 3 (see figures 6.1o and 6.1p below).

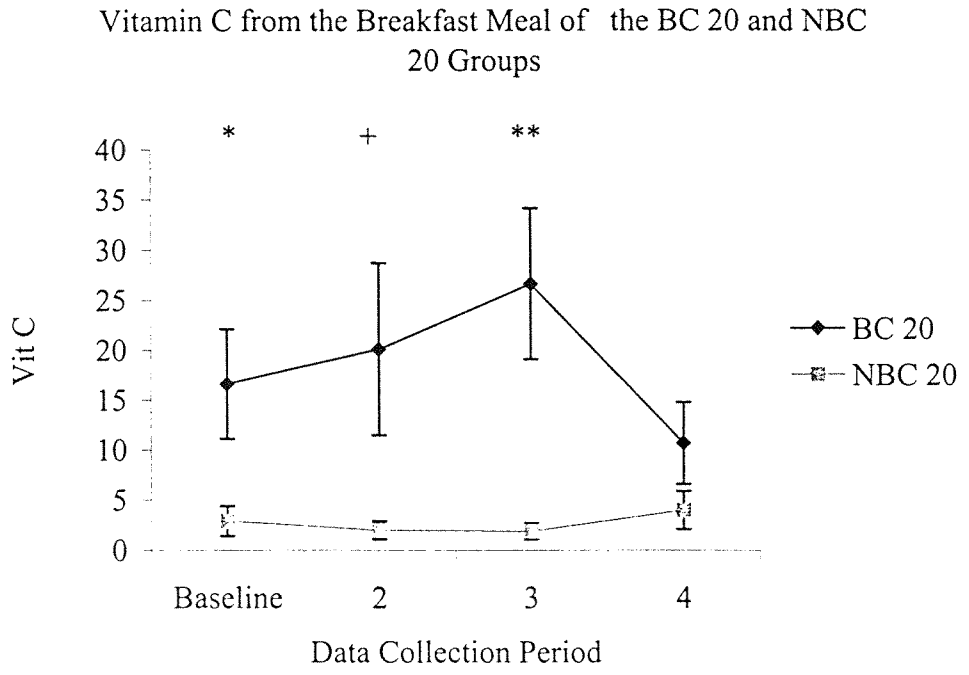


Figure: 6.1o Vitamin C from the Breakfast Meal of the BC 20 and NBC 20 Groups where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

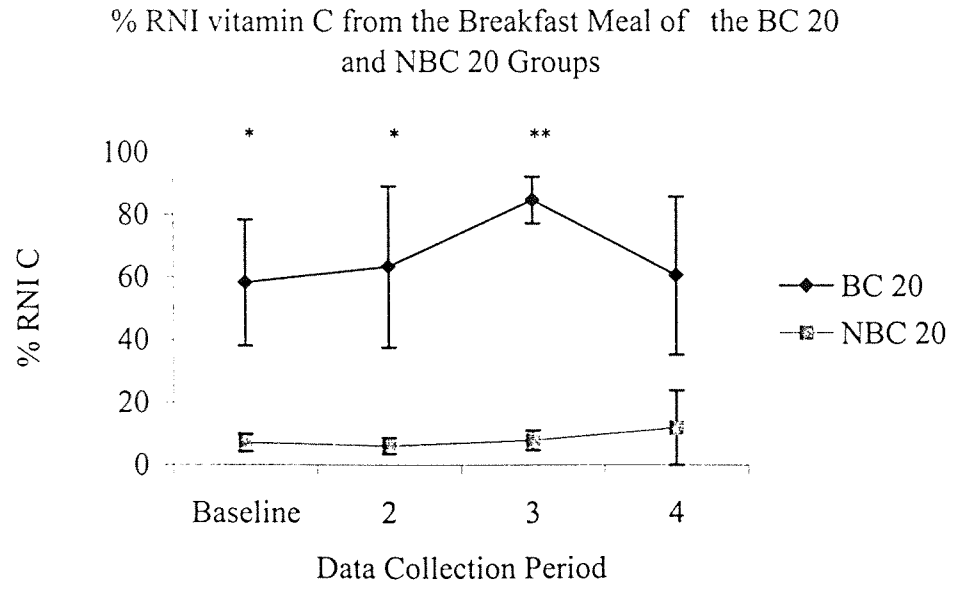


Figure: 6.1p % RNI vitamin C from the Breakfast Meal of the BC 20 and NBC 20 Groups where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

Vitamin A intakes were also greater in the breakfast consumed by the BC 20 group and figure 6.1q show that the difference in intakes of this vitamin between the groups was significant for or lose to significance at data collections 3 and 4.

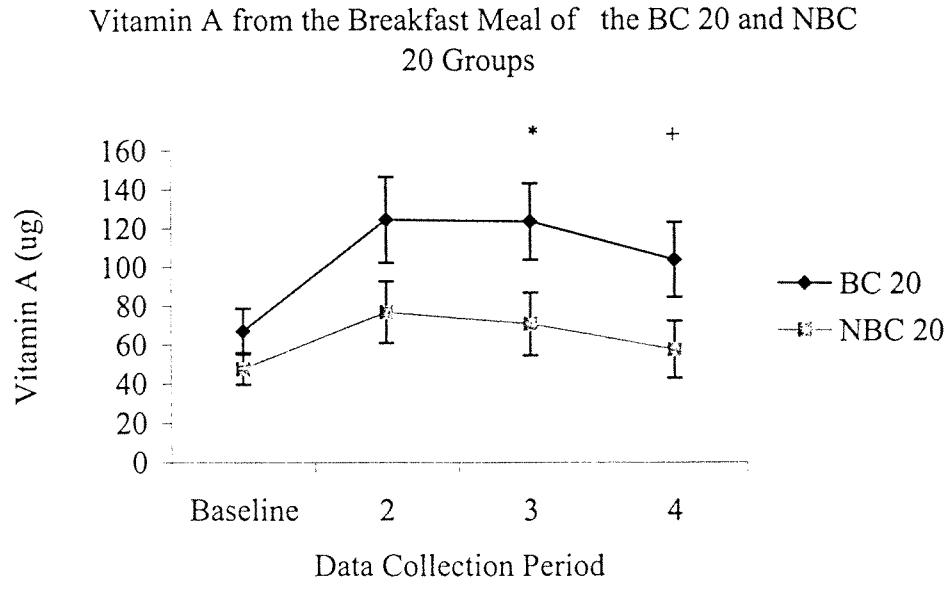


Figure: 6.1q Vitamin A from the Breakfast Meal of the BC 20 and NBC 20 Groups
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

The amount of vitamin D available from the breakfast meal at data collections 3 and 4 were significantly greater for the BC 20 group (see figure 6.1r).

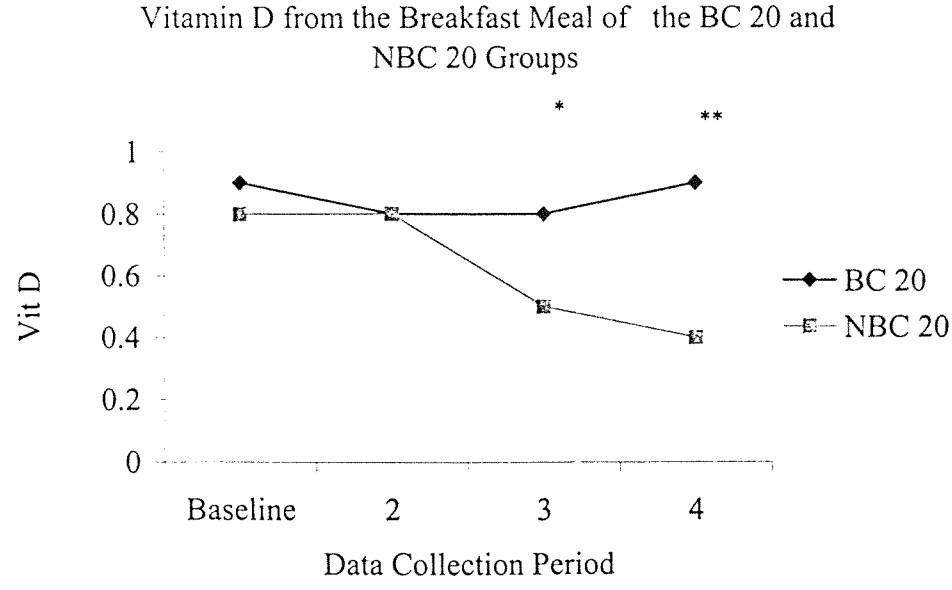


Figure: 6.1r Vitamin D from the Breakfast Meal of the BC 20 and NBC 20 Groups
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

6.1.3 Discussion

The percentage of energy from fat from breakfast was lower in the NBC 20 group than the BC 20 group. The contribution of fat to this meal was likely to be from cooked breakfasts, butter or margarine on toast, confectionary and crisps that were consumed at this meal . Whilst there was no significant difference in the amount % energy of fat but there was significant difference in the amount of fat *per se* between the groups. The BC 20 breakfast had between 10-15g of fat whereas the NBC 20 group consumed between 5-8g of fat. This had an impact of the % RNI of fat from the breakfast meals and whilst the BC 20 group were getting 15-20% of the RNI for fat at breakfast at data collections 2,3 and 4 the NBC 20 group were achieving 10-15% at these data collection points. The consumption of fat at breakfast may have an impact on blood lipid levels. Examination of the breakfast habits of 530 U.S children, ages 9-19, found lower blood cholesterol levels among those who consume a cereal breakfast than those who regularly skipped breakfast (Reniscow *et al.,* 1981). More recently re-analysis of the NDNS data showed that high consumption of breakfast cereals was associated with lower blood levels of total cholesterol and LDL cholesterol (Gibson, 2003).

Protein which is a vital nutrient for growth and is so especially important for children of this age made up 11% of the energy fro the breakfast meals at baseline. The breakfast meal was an important contributor to the % RNI for protein since this meal provided 27.1±4.1% RNI protein for the BC 20 group and 22.4±4.1% for the NBC 20 group. Health care professionals recommend that breakfast provided 25% a quarter of the recommended daily amount of nutrients. Breakfast at baseline was providing the children with an adequate amount of protein.

Ca is also an important nutrient for growth breakfast at baseline was providing over 20% of the RNI for this vitamin. The source of this Ca was from milk consumed with cereal , Ca fortification of cereal and dairy spreads on toast.

The breakfast meal also provided over 20% of the % RNI Fe which is another vital nutrient needed for growth development and weight gain. The cooked breakfasts and fortified breakfast cereals would have contributed to this Fe in the breakfast meal. An average serving of a fortified breakfast cereal contributes 17% of the recommended daily amount of iron. In the UK, it has been estimated that breakfast cereals provide 20% of the total Fe intake of preschool children (meat provided 14%). For children consuming most breakfast cereals (top third), nearly one-third of the total daily Fe intake was from this source (Gibson, 1999). Results of the National Diet and Nutrition Survey show that breakfast cereals and bread were major contributors to Fe intake accounting for about 50% of Fe intake, for young people (Buttriss , 2002). Breakfast cereals alone contribute more than 20% of children's Fe intake (Gibson, in press).

Breakfast contributes to the nutritional quality of the diet, especially to such problem nutrients as iron and calcium. The missed contribution of energy and nutrients as a result of missing breakfast is not on average , compensated for in subsequent meals and snacks (Chao and Vanderkooy, 1989). Vit A which is another crucial vitamin for growth and normal development and differentiation of tissues was available in greater amounts in the BC 20 breakfast 22.0% RNI Vit A as compared to 11.6±2.6 % RNI in the NBC 20 group. At baseline 25% of children in the BC 20 group were eating cereal and a cooked breakfast over the 3 –days of data collection and a further 5% were eating a cooked breakfast or toast. The use of fortified dairy spreads is likely to have had an impact on the larger vit A intakes of this group. The difference between the groups however was not significant.

The B-vitamins were present in the breakfast meal in adequate amounts and both groups were getting over 25% of these vitamins from the baseline breakfast. The % RNI achieved

from the breakfast meal for B2, nicotinic acid and B12 was over 40% in both groups. This is due to be likely to the consumption of fortified breakfast cereals. A serving of most fortified cereals provide at least 25% of the recommended daily amount of vit B1, B2, B12, and folic acid. Teenagers who regularly consumed cereal are more likely to meet the dietary guidelines (RNI) for B vitamins, Fe, Ca and zinc (Crawley, 1993). McNulty at al 1996 also found that children not eating cereals were found to have intakes of B2, niacin, folate and B12 well below the lower reference nutrient intake . A recent evaluation of the NDNS revealed that breakfast cereals provided over 25% of total dietary B1, B2, niacin, vitamin B6, folic acid and vitamin D for high cereal consumers (Gibson, 2003).

The only difference between the groups at baseline was that the BC 20 had higher intakes of vitamin C, i.e. 16.6±5.5 mg versus 2.9±1.5 mg in the NBC 20 group ($p \leq 0.05$). This meant that the BC 20 group were gaining a much higher % of the RNI for vitamin C from the breakfast meal 58.2±20.1 % versus 7.1±2.9($p \leq 0.01$). This was due to a higher consumption of fruit juice in the BC 20 group at baseline.

Data Collections 2,3 and 4

The BC 20 group ate significantly greater amounts of calories at the breakfast meal than the NBC 20 group at data collection 2 and 3 . They were consuming between 370-390 kcals at breakfast over these 2 data collection periods as compared to 220-260 kcals for the NBC 20 group. Health care professionals recommend that 25% of the RNI for calories should be consumed at the breakfast meal. Children of this age group should be eating 1 970 kcal (boys) or 1740 kcal (girls). Therefore this higher calorie intake of the BC 20 group is closer to these recommendations.

However this greater amount of calories is due to a greater amount of fat in the BC 20 breakfasts. Health care professionals recommend that no more than 35% of energy comes from fat. Whilst the BC 20 breakfasts did not exceed this value it is likely that this greater amount of fat at breakfast will affect fat intakes over the day. At the second data collection point 38% of children ate a cooked breakfast at the breakfast club and a further

26% had a cereal and cooked breakfast . In comparison the only 12 % of children in the NBC 20 group had a cooked breakfast whilst over 50% ate cereal only. A similar pattern existed at data collection 4 with more children in the BC 20 group eating a cooked breakfast and more children in the NBC 20 group eating a cereal breakfast. At data collection 3 there were less cooked breakfasts being consumed by the BC 20 group than at the previous measurement but there was an increase in toast consumption. There were a large percentage of cereal eaters in the NBC 20 group at point 3. The cooked breakfasts increased the amount of fat in the breakfast, since the rolls served at school were filled with either sausage, egg, black pudding, bacon or cheese. Each roll also contained 10g of sunflower or olive margarine spread which also accounted for the higher fat content of these breakfasts. At time period 3, cooking facilities were restricted in one of the breakfast club schools and only cheese or egg toasties were available at this school. However each toastie contained 10g of sunflower or olive margarine. A recent study by Cho showed that breakfast cereal eaters had lower fat intakes and higher vitamin intakes than those eating pastries or ham and eggs for breakfast (Cho *et al.,* 2003). Different types of breakfast were also investigated by Preziosi *et al.* (1999) and cereal consumption was associated with a greater proportion of daily energy from CHO and a lower proportion of energy from fat . A low fat high CHO diet breakfast has been shown to be physiologically important in that it primes the body's metabolism for handling subsequent fatty meals (Frape *et al.,* 1994).

At all 3 data collection points PUFA and MUFA was significantly greater in the breakfast served at school and consumed by the BC 20 group. This affected the percentage energy from this fat and fat intakes overall. This larger amount of PUFA and MUFA was due the use of thickly spread sunflower or olive margarine. It is recommended that no more than 6.5% of energy comes from PUFA. The breakfasts of the BC 20 group was approximately 6% at data collections 2,3 and 4. It also recommended that no more than 13 % of energy comes from MUFA. The BC 20 group breakfast had approximately 9% of the energy from MUFA whereas % energy from MUFA for the NBC 20 group was around 6%.

The % RNI SAT from the breakfast meal was also higher in the BC 20 group and significantly so at data collection 3. This was due to the meat consumed at the breakfast club).

CHO was consumed in greater amounts by the BC 20 group also. This was to the consumption of bread, orange juice and hot drinks at the breakfast club. This meant that there was more of both starch and sugar in the BC 20 breakfast. Milk and milkshakes were available at the breakfast club and this has had an impact on Ca consumption which is greater for the BC 20 group but there is only a significant difference between the groups at period 3. The NBC 20 group were consuming milk with their cereal which is the reason that there is only a difference between the group at one data collection period. The breakfast meal provided over 20% of the RNI for this vitamin in both groups. Vit C intake was higher in the BC 20 group at all time periods. The breakfast club offered fresh orange and apple juice and as a consequence vit C intakes were high in this group. Intakes of vit A were also greater for the BC 20 group. The margarines used in the hot rolls were fortified with vit A which has resulted in significantly greater amounts of this vitamin at data collection 3.

6.2 The Change in Breakfast Intake from Baseline

The change in nutritional composition of the breakfast meal consumed at baseline and that consumed at data collection 2,3 and 4 by the BC 20 and NBC 20 group has been explored in this chapter. This has been calculated by subtracting the breakfast at baseline nutritional values from the breakfast at data collection 2,3 and 4, i.e.

difference in nutritional composition of breakfast = nutrient value of breakfast at data collection 2,3 or 4 minus nutrient value for breakfast eaten at baseline

The purpose of this chapter therefore is to explore the changes in macro and micronutrient intake from the baseline breakfast to the breakfast eaten at data collection 2 ,3 and 4 and the change in % RNI of these nutrients. This chapter will examine the differences in these changes between the BC 20 and NBC 20 groups.

Table 6.2a Number of Subjects in the BC20 and NBC20 Group for the change in nutrient intake at Breakfast Meal form Baseline

	Baseline to Data 2	Baseline to Data 3	Baseline to Data 4
BC 20	15	18	16
NBC 20	15	16	17

Table: 6.2b Subject Characteristics of the BC 20 and NBC 20 Group for the Breakfast Meal Nutrient Analysis

	BC	NBC
	Baseline to Data 2	
Age	9.6(± 0.3)	9.3(± 0.3)
Gender	7F:8M	10F:5M
	Baseline to Data 3	
Age	9.8(± 0.2)	9.3(± 0.2)
Gender	9F:9M	9F:7M
	Baseline to Data 4	
Age	9.9(± 0.2)	9.6(± 0.2)
Gender	7F:9M	11F:6M

6.2.1 Change in Breakfast Intake from the Breakfast at Baseline for the BC and NBC Groups

Macronutrient Changes from the Breakfast at Baseline to Breakfast at Data collections 2,3 and 4.

Calories increased from the breakfast consumed at baseline to the breakfast eaten at school at data collection 2, 3 and 4 for the BC 20 group. The increase in calories for the NBC 20 who ate breakfast at home was only marginal. As indicated in fig 6.2a at data collections 2 and 3 this difference in the increase in calories between the 2 group was significant ($p \leq 0.05$).

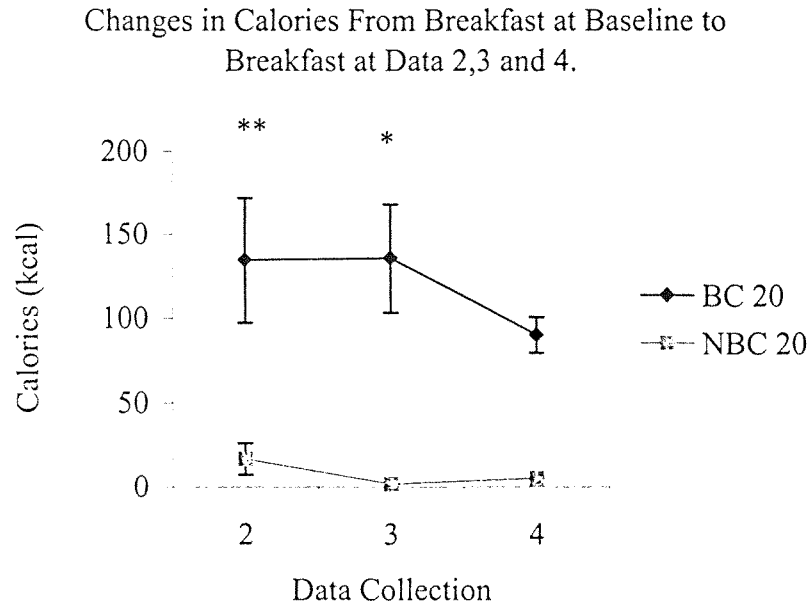


Fig: 6.2a Changes in Calories From Breakfast at Baseline to Breakfast at Data 2,3 and 4.

where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

There was an increase in % RNI protein from the breakfast consumed at school by the BC20 group when compared to the breakfast consumed at home at baseline. For the NBC 20 group there were marginal changes from the baseline breakfast. At data collection 2 the difference in the change of % RNI from breakfast was significant ($p \leq 0.05$) (see figure 6.2b below).

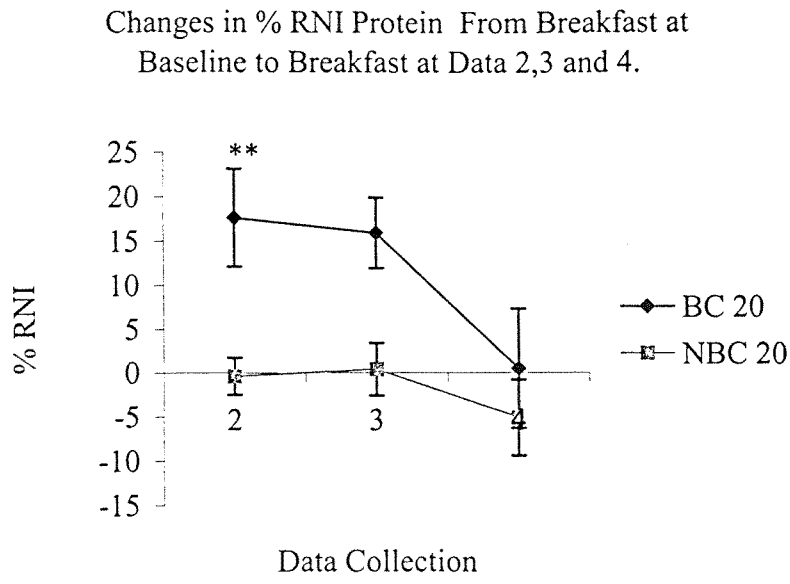


Fig: 6.2b Changes in % RNI Protein From Breakfast at Baseline to Breakfast at Data 2,3 and 4.
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

At all 3 data collection periods there were increases of more than 2g of PUFA at the breakfast meal for the BC 20 group. As illustrated in figures 6.2c – 6.2d this increase in PUFA also increased % energy from this fat by 3-4% at all 3 time periods and increased the % RNI of PUFA from the breakfast meal by 15-20%.

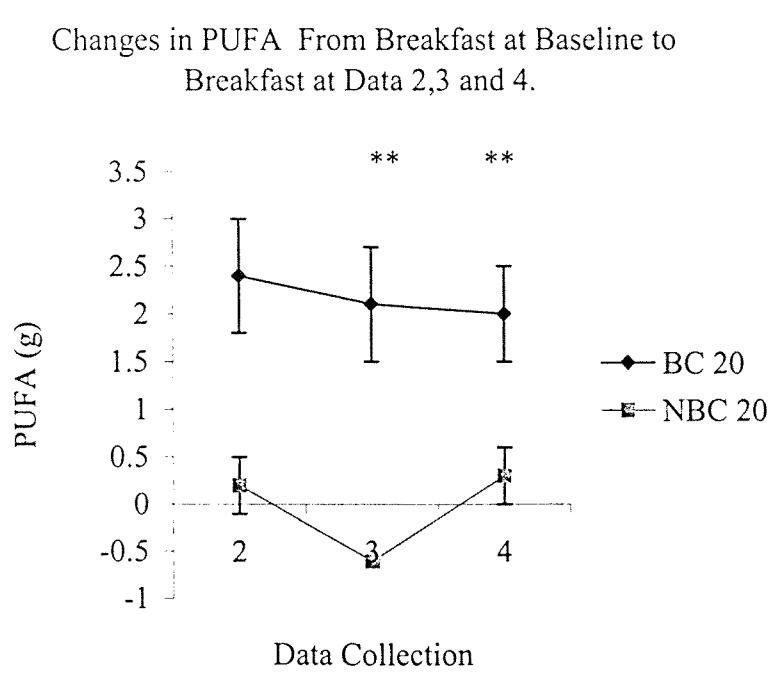


Figure 6.2c Changes in PUFA From Breakfast at Baseline to Breakfast at Data 2,3 and 4.

where * p ≤ 0.05 , **p ≤ 0.01 and ***p ≤0.001

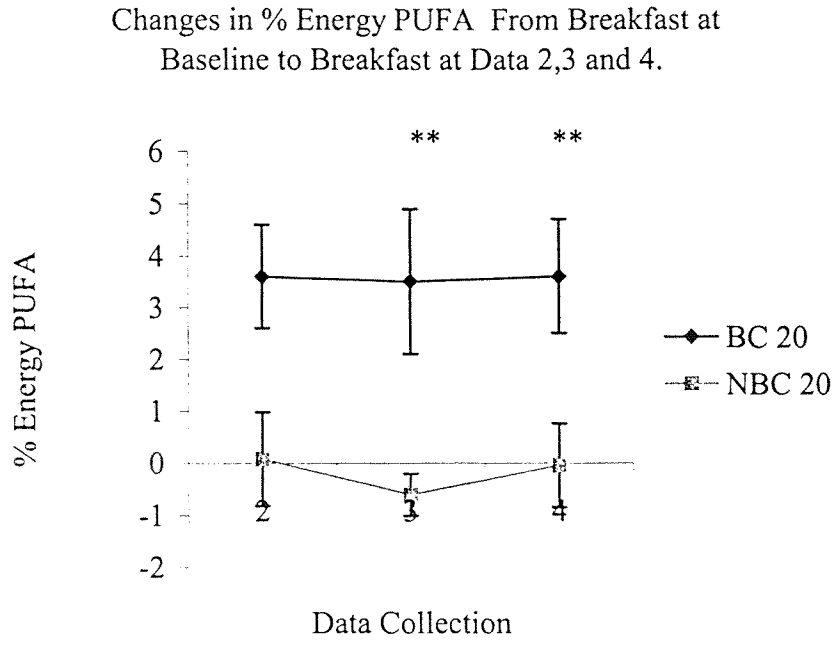


Fig: 6.2d Changes in % Energy PUFA From Breakfast at Baseline to Breakfast at Data 2,3 and 4.

(where * p ≤ 0.05 , **p ≤ 0.01 and ***p ≤0.001)

Intakes of MUFA also increased by 2- 3g from the baseline breakfast at all 3 data collections for the BC 20 group. MUFA intakes also increased marginally for the NBC 20 group and the differences in the magnitude of the increases of this fat as significant at data collections 2 and 3 as depicted in figure:6.2e below.

Changes in MUFA From Breakfast at Baseline to Breakfast at Data 2,3 and 4.

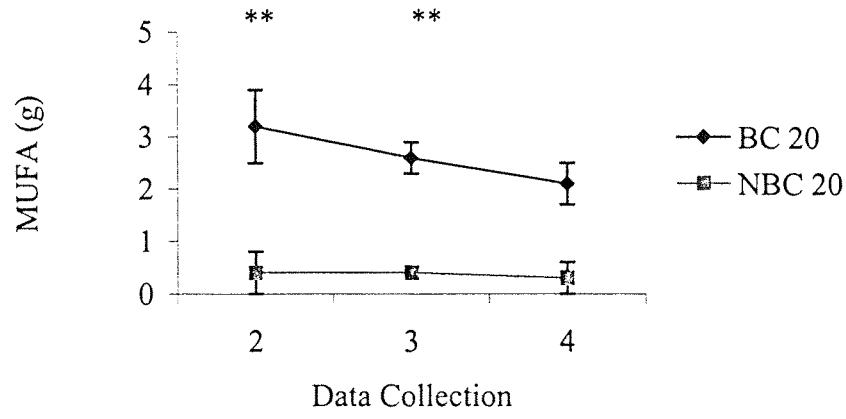


Fig: 6.2e Changes in MUFA From Breakfast at Baseline to Breakfast at Data 2,3 and 4.

where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

The amounts of starch in the breakfast meals increased from the baseline measurement for the BC 20 group. As indicated in fig: 6.2f the amount of starch from the breakfast meals showed a decrease from the baseline measurement at collection 3 and 4 the NBC 20 group.

Changes in Starch From Breakfast at Baseline to Breakfast at Data 2,3 and 4.

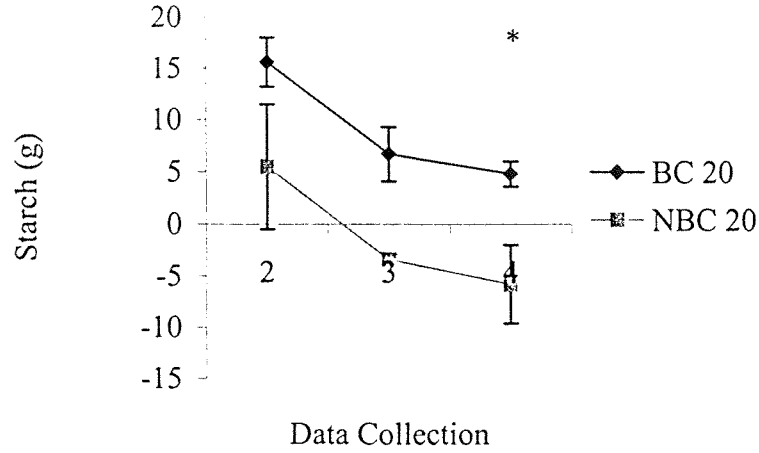


Fig: 6.2f Changes in Starch From Breakfast at Baseline to Breakfast at Data 2,3 and 4.

where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

Micronutrient Changes from the Breakfast at Baseline to Breakfast at Data collections 2,3 and 4.

There was an increase of over 100 mg of Ca intake for the BC 20 group at data collection3 and 4. As shown in fig: 6.2g the NBC 20 group showed only very small changes in Ca intakes. At data collection 4 there was only a marginal increase in Ca for the BC 20 group also. The increases in Ca intake at data collection 2 and 3 meant that there were increases in % RNI for this nutrient of over 10%.

Changes in Calcium From Breakfast at Baseline to Breakfast at Data 2,3 and 4.

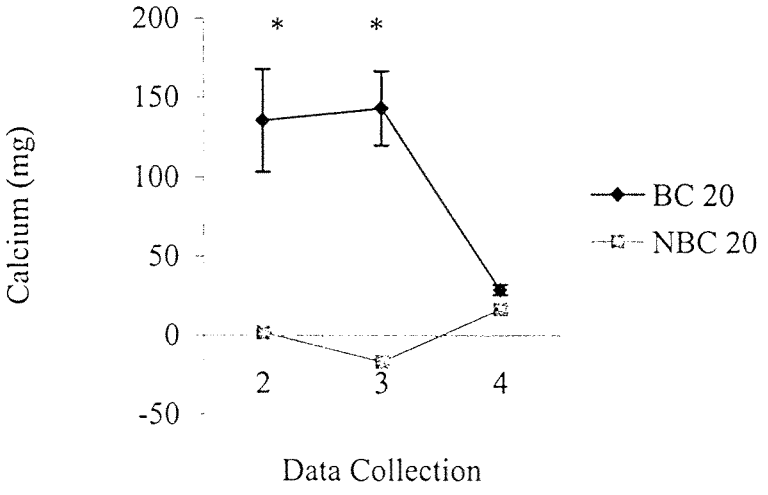


Fig:6.2g Changes in Calcium From Breakfast at Baseline to Breakfast at Data 2,3 and 4

where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

Intakes of vit C increased from the baseline measurement for the all data collection points for the BC 20 group and at 3 data collection periods there was an increase in of 10 - 35 % RNI for vit C for this group (see figure 6.2h). Changes in vit C for the NBC 20 group were small.

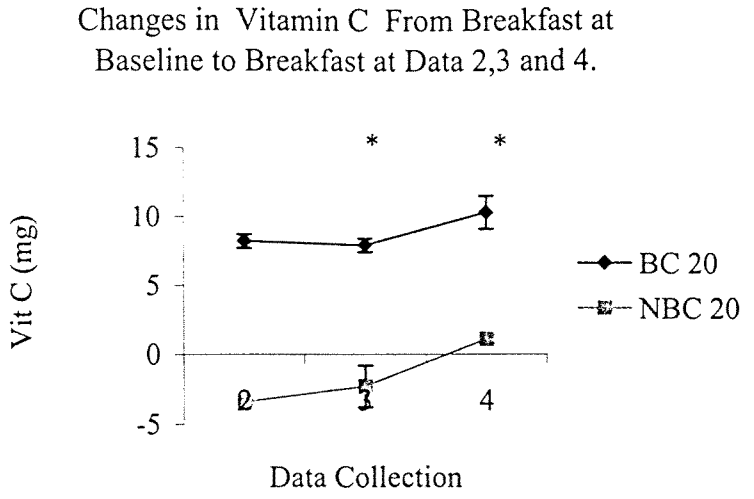


Fig : 6.2h Changes in Vitamin C From Breakfast at Baseline to Breakfast at Data 2,3 and 4.
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

Vitamin A intakes also increased at each time period for the BC 20 group. At data collection 3 however this increase was only marginal for the BC 20 group as shown in figure 6.2i below. The NBC 20 group showed an increase in this vitamin at data collection 2 only and by data collection 4 this vitamin had decreased from the baseline measurement.

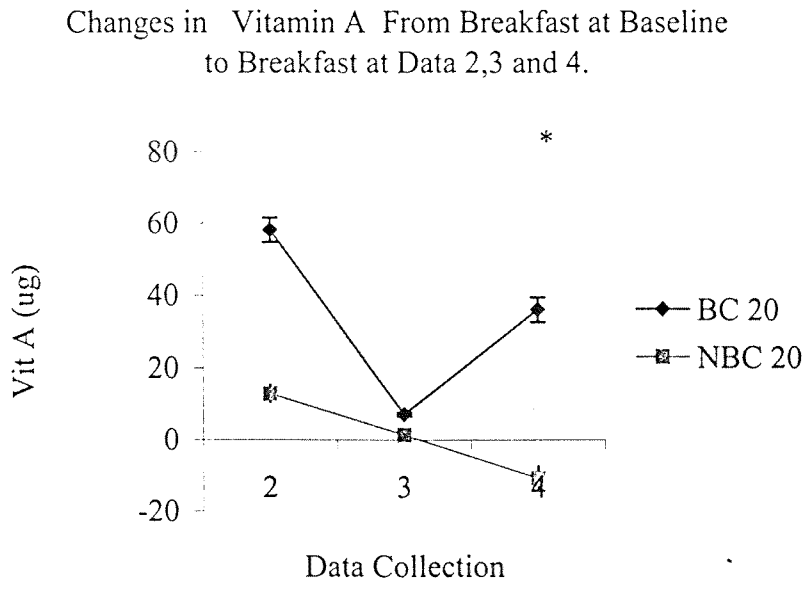


Figure: 6.2i Changes in Vitamin A From Breakfast at Baseline to Breakfast at Data 2,3 and 4.
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

6.2.2 The Breakfast Meal Compared to Breakfast at Baseline

The breakfast consumed at baseline (when all breakfasts were eaten at home) was compared to the breakfasts eaten by the BC 20 and NBC 20 groups at data points 2, 3 and 4. The paired Student's t-test was used to compare baseline breakfasts for each group with the subsequent breakfast meals. Tables 6.2c and 6.2d below illustrate the differences between baseline breakfast and breakfast at each data collection point 2,3 and 4 for each of the BC 20 and NBC 20 groups. The differences found mirror the differences found between the groups when the change from baseline was explored.

Table: 6.2c Macronutrient Differences of Breakfast at Baseline Versus Breakfast at Data Collection 2, 3 and 4 for the BC 20 and NBC 20 groups

	BC 20 Baseline Versus Data 2	NBC 20 Baseline Versus Data 2	BC 20 Baseline Versus Data 3	NBC 20 Baseline Versus Data 3	BC 20 Baseline Versus Data 4	NBC 20 Baseline Versus Data 4
Calories (Kcal)	✓		✓			
% Energy Fat	✓					
Protein (g)	✓		✓			
% RNI Protein			✓			
Fat (g)			✓			
PUFA (g)	✓		✓		✓	
% Energy PUFA	✓				✓	
% RNI PUFA	✓		✓		✓	
MUFA (g)	✓		✓		✓	
% Energy MUFA			✓		✓	
% RNI Fat	✓		✓			
% RNI SAT	✓					
CHO(g)			✓			
% RNI CHO			✓			
Starch (g)	✓					

where ✓ represents a significantly greater amount of nutrient at data 2,3 or 4 than the baseline measurement
and × represents a significantly smaller amount of nutrient at data 2,3 or 4 than the baseline measurement

Table : 6.2d Summary of the Micronutrient Differences Breakfast at Baseline Versus Breakfast at Data Collection 2, 3 and 4 for the BC 20 and NBC 20 groups

	BC 20 Baseline Versus Data 2	NBC 20 Baseline Versus Data 2	BC 20 Baseline Versus Data 3	NBC 20 Baseline Versus Data 3	BC 20 Baseline Versus Data 4	NBC 20 Baseline Versus Data 4
Calcium (mg)	✓		✓			
% RNI Calcium			✓			
Vitamin C (mg)	✓		✓			
% RNI Vitamin C	✓		✓		✓	
Vitamin A	✓		✓			
% RNI Vitamin A	✓		✓			
% RNI Vitamin B6	✓					
Vitamin D (ug)			✓			

Where ✓ represents a significantly greater amount of nutrient at data 2,3 or 4 than the baseline measurement
And × represents a significantly smaller amount of nutrient at data 2,3 or 4 than the baseline measurements

6.2.3 Discussion

At data collections 2 and 3 there was a significant difference in the calories of the BC 20 and NBC 20 breakfast (see chapter 6.1). The difference in calories of the breakfast eaten at baseline compared to the breakfast eaten at data collection 2 and 3 of both groups was also significant. The increase in calories from the breakfast at baseline for the BC 20 was 100-140 kcals. Calories from breakfast of NBC 20 group stayed the same. This is to be

expected since there were a high percentage of cereal eaters at all three time periods in the NBC 20 group. Calories in the BC 20 group would be expected to rise from the baseline measurements since there was a significant fall in cereal only eaters and a rise in cooked breakfast eaters at all data collection points.

There was a significant difference in the amount protein *per se* in the breakfast meals of the BC 20 and NBC 20 at all 3 data as discussed in the previous chapter. When the change from baseline was explored however there was only a significant difference between the groups in % RNI of protein at data collection 2. This suggest that protein is the one nutrient that has been the least affected by the breakfast club in terms of achieving the recommended daily intake.

Whilst there were significant differences for total fat intake between the BC 20 and NBC 20 groups at data collections 2,3 and 4, this difference did not manifest itself when the changes from breakfast at baseline were explored. This signifies that whilst there was a difference in the nutrient composition of the breakfasts between the 2 groups of children , the change in total fat intakes from baseline (before the commencement of the breakfast club) was not affected. At baseline some of the children were eating cooked breakfast and confectionary and crisps for breakfast. This would have increased the total fat content of the breakfast meal.

There were significant differences in PUFA(grams), % energy PUFA and % RNI PUFA consumed at breakfast by the 2 groups at data collections 2,3 and 4. The BC 20 group were eating 2-1.5 g more of PUFA than they ate at the baseline breakfast, where their intake was similar the NBC 20 group at below 1g. When the difference from baseline was explored there were significant differences between the groups at data collection 3 and 4 only. This could be due to the fact that at this particular data collection point PUFA intakes were slightly higher at baseline for the NBC 20 group and this will be explored in the next chapter (6.3). The change in % RNI for PUFA was significantly higher for the BC 20 at all 3 data collection periods, whilst there were no changes for the BC 20 group. The

increases in PUFA were due to the use of 10g of sunflower spread in the hot filled rolls at the breakfast club. There were no such increases in the NBC 20 group since there were significantly greater amounts of cereals eaters at all 3 data points.

Intakes in MUFA had also increased significantly from the baseline measurement for the BC 20 group as compared to the NBC 20 group. The increase was also evident when the change from the baseline breakfast was explored at data collections 2 and 3. This increase in MUFA was because of the use of olive spread by one of the breakfast club schools.

These increases in PUFA and MUFA may at first appear to be something that should be encouraged, in that eating these types of fats should reduce SFA and other more harmful fats. However this cannot be elucidated until total fat and calorie intake is examined (chapter 6.4).

There were increase in starch (grams) at 3 data collection points for the BC 20 group and this is likely to be due to the toast, bread rolls and cereal at the breakfast club. An observation by staff at the breakfast club was that children did tend to eat more than they might do at home and this has probably also had an effect on starch intakes. The amount of starch NBC 20 group fluctuated only slightly. Research has indicated that a high CHO breakfast can make a major contribution to a reduced fat intake for the entire day (Crawley, 1993). This will be investigated futher in chapter 6.3 and 6.4.

Ca intakes increased for the BC 20 group by 130- 150mg at data collection 2 and 3 for the BC group whereas there was no increase in the NBC 20 group. The breakfast club offered fresh milk and milk shakes and so whilst there was a decreased in cereal consumption (which encourages milk consumption (Nicklas *et al.,* 1998) the change in breakfast type did not detrimentally affect Ca intake. The children in the BC 20 group were increasing their % RNI for Ca by 10-23% from the breakfast meal only at data collections 2 and 3. At data collection 4 the difference between the groups was not evident. The final data collection took place in May/June at which point the children preferred to drink orange

juice and diluting juice in preference to milk which is a likely reason for this fall in Ca intakes.

The supply of fresh orange juice and fruit juice at the breakfast clubs meant that there was an increase from the baseline breakfast in vit C intakes and the increase in this vitamin for the BC 20 group meant that there was a 10-30% increase in the % RNI of vit C from the breakfast meal. Intakes of vit C fluctuated to a small degree in the NBC 20 group. Intakes of vit C increased in the BC 20 group over time and this reflected the preference of the children to drink juice over hot drinks on the onset of spring and summer. NDNS data shows that fresh juice was the biggest contributing food to vit C intakes in all children (NDNS, 2003).

Vit A intakes at breakfast were higher for the BC 20 group than the NBC 20 when the 2 breakfasts were compared at data collections 2, 3 and 4. At data collection 3 there was a significant difference between the groups but when the change from breakfast at baseline was explored the difference between the groups did not exist. This could be due to a higher vitamin A intake of this particular baseline group at baseline.

Breakfast eaters are more likely to meet their needs for nutrients such as vit A and vit C, (Tietyen *et al.*, 1995) and these results reflect that the breakfast club did contribute to intakes of these 2 vitamins along with Ca.

6.3 Total Daily Intake

Dietary intake was assessed using 3-day estimated food diary as described in chapter 2.3. The mean of the 3-days of intake was calculated and has been presented in this chapter for the BC 20 and NBC 20 groups.

The purpose of this chapter therefore is to investigate the differences between total dietary intake for the day for the BC 20 and NBC 20 group at baseline (before the commencement of the breakfast club), data collection 2 ,3 and 4, and to investigate the difference between the groups (using independent t-tests). The change from baseline intake to daily intake at data collections 2 ,3 and 4 have also been explored and theses are also represented in the tables below when statistically significant differences between the groups were found.

Table 6.3a Number of Subjects in the BC and NBC Group for the Breakfast Meal Nutrient Analysis

	Baseline	Data Collection 2	Data Collection 3	Data Collection 4
BC 20	16	11	13	13
NBC 20	20	17	13	16

Table: 6.3b Subject Characteristics of the BC 20 and NBC 20 Group for the Breakfast Meal Nutrient Analysis

	BC 20	NBC 20
Baseline		
Age	9.4(± 0.3)	9.8(± 0.2)
Gender	7F:9M	10F:10M
Data Collection 2		
Age	9.4(± 0.3)	9.9(± 0.3)
Gender	5F:6M	8F:9M
Data Collection 3		
Age	9.7(± 0.4)	9.7(± 0.4)
Gender	5F:8M	5F:8M
Data Collection 4		
Age	9.7(± 0.4)	10.4(± 0.4)
Gender	5F:8M	8F:8M

Under-reporters

Estimated intakes were compared to BMR as described in chapter 2.3 and the percentage of children under-reporting could be calculated using a CUT-OFF point. At baseline we can assume that 98% of the children were reporting their dietary intakes accurately. There was an average estimated intake of 722.7 (±302.4) kcal more than the BMR. Only 2% of children were under-reporting.

6.3.1 Baseline- October/November 2000

Differences In Macronutrient Composition of the BC20 and NBC20 Groups for Total Day Intake at Baseline

At baseline the BC20 were consuming 2003.7±85.8 kcals and the NBC20 group had 1828.2± 74.8 kcals for their total daily intake of calories . This meant that both groups were achieving the recommended amount of energy. The BC20 group achieved 99.8%± 5.7% RNI for calories whilst the NBC20 group consumed 99.4± 5.9%.Percentage energy from protein was greater in the BC20 group. This macronutrient provided 15.9±2.2% of energy for the BC20 breakfast group whereas 11.5± 0.5%of energy came from this source for the NBC20 group ($p \leq 0.05$).

There was only a 1.2% energy difference in fat between the groups. The RNI for fat is 35% and so the NBC20 group were closer to these recommendations at 35.3± 1.5% than the NBC20 group whose percentage energy from fat was 36.5± 1.2%. Percentage energy from SFA was equal in both groups both group at 13.6±0.7%and 13.3±0.7%for the BC20 and NBC20 groups respectively. The DRV for % SFA is 10% of energy and so both groups were in excess of recommended amounts ($p \leq 0.001$). PUFA were present in the diets of both groups in similar amounts and percentage energy from this type of fat was 6.1± 0.5% for the BC20 diet and 6.2±0.6% for the NBC20 daily intake. Both groups were below the recommended 6.5% energy form type of fat. Both groups were also below the DRV for MUFA. The recommended % of energy from this source is 13%. The BC20

this source is 13%. The BC20 group had 12.1±0.8% of energy from this source whereas the NBC20 group had 11.2±0.6% of energy from MUFA. The difference in % energy MUFA for the BC20 group and the DRV is 1.8% ($p \leq 0.05$).

There was a 6.6% difference in percentage energy from carbohydrate between the groups. DRVs are that 50% of daily energy comes from CHO and the BC20 group had 45.7± 3.0% of their energy from this source whereas the NBC20 group had 52.3% of their energy from this macronutrient. DRVs for starch and sugar are 39% and 11% respectively. As illustrated in table 6.4c both groups were below the DRV for starch and above the recommended amounts for sugar. However there were no differences between the groups for percentage energy of these CHO sources. There were no differences in the intake of fibre of the 2 groups. The BC20 group consumed 9.9± 0.6g whereas the NBC20 group had 10.3± 0.7g.

Differences In Micronutrient Composition of the BC and NBC Group for Total Day Intake

There were no differences in the amount of Ca in both groups and as indicated in table 6.4d both groups were over 100% for the DRV for Ca. Fe which is often low in school children of this age (NDNS, 2000) was adequate for the BC20 group but 12.1% lower than the RNI for the NBC20 group. There was a difference in the amount of vitamin C between the 2 groups. As indicated in table:6.4d the BC20 group had 95.7± 23.3mg of this micronutrient whereas the NBC20 group had 44.2± 5.5mg in their daily diet at baseline ($p \leq 0.05$). The BC20 were achieving 230.3±39.2% of the % RNI for vitamin C whereas the NBC were only over the RNI by 37.8±17.2%. The BC20 group were 23.6% below the RNI for vitamin A whereas the NBC20 group were only 4.3% under the recommended amount. Both groups were achieving over the RNI for all the B-vitamins at baseline and there were no differences between the groups. Vitamin B_{12} was the micronutrient which was present in the greatest excess since the BC20 diet at baseline had 368.0± 72.3% of the RNI for this vitamin whereas the NBC20 group had only 259.1± 27.9%. Folate was the vitamin which

was present in both groups daily diets which was closest to the RNI. The BC20 group had a diet which provided the children with 11.5±12.4% over the RNI whereas the BC20 breakfast was only 0.4± 10.1%.

6.3.2 Differences in Daily Macronutrient Intake During Data Collections 2, 3 and 4 For the BC and NBC Groups

At both all 3 data collection periods including the baseline measurement the BC 20 group were consuming more calories than the NBC 20 group. As illustrated in figure 6.3a below there was a significant difference between the groups at data collection 4. Figure 6.4b shows that the children were consuming the RNI or just above the RNI for calories at each data collection point.

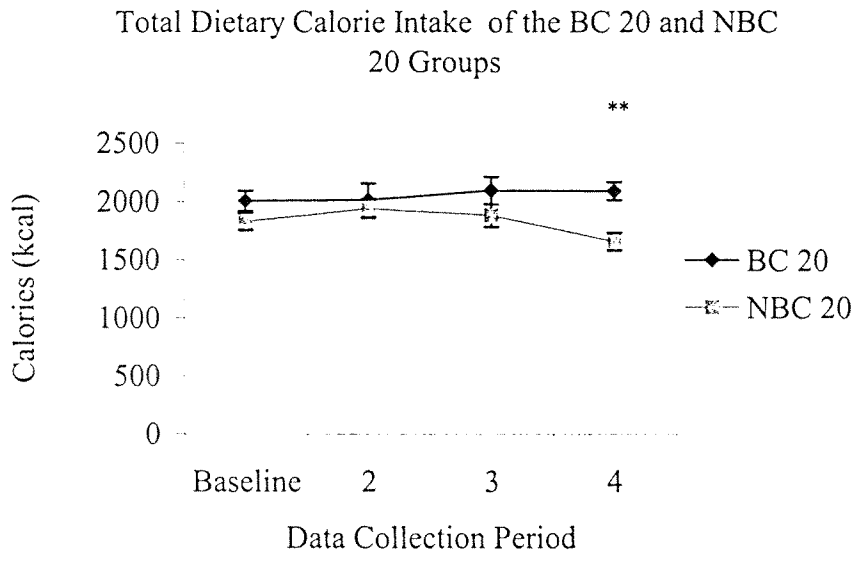


Figure: 6.3a Total Dietary Calorie Intake of the BC 20 and NBC 20 Groups
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

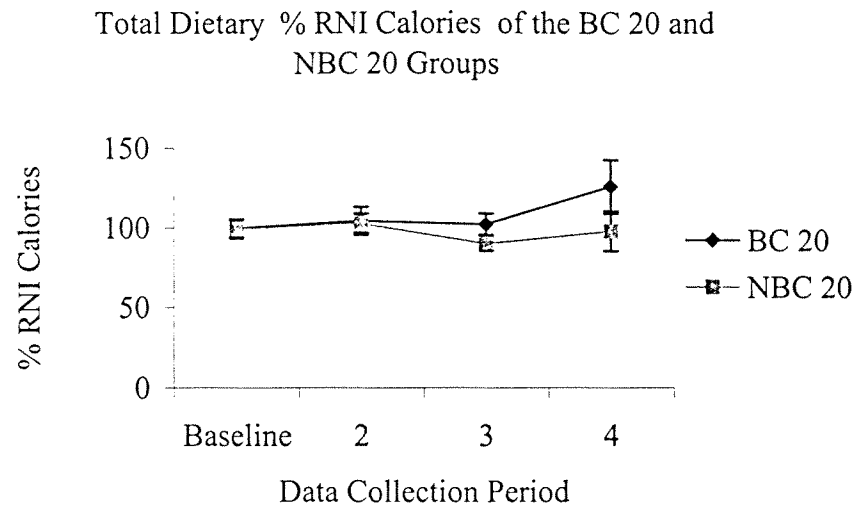


Figure: 6.3b Total Dietary % RNI Calories of the BC 20 and NBC 20 Groups
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

The BC 20 group had a higher % energy from protein but this was only significant at baseline (as illustrated in figure 6.3c below).

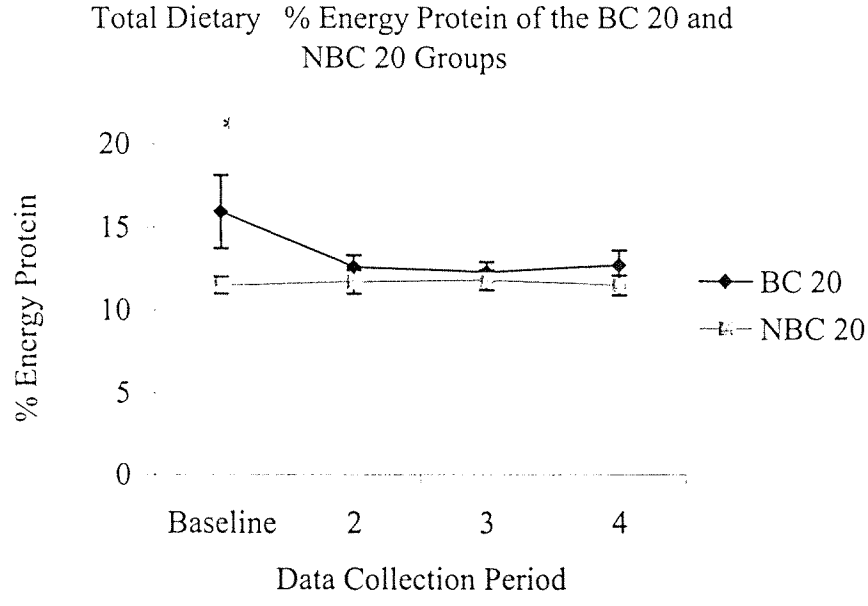


Figure: 6.3c Total Dietary % Energy Protein of the BC 20 and NBC 20 Groups
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

Dietary fat intakes were higher for the BC 20 group at all data collection periods and significant at data collection 4 (see figure 6.3d). The percentage energy for fat was also significant at data collection 4 for the BC group (see figure 6.3e). Figure 6.3f illustrates this point further where both groups are achieving over 100% of the RNI for fat.

Total Dietary Fat of the BC 20 and NBC 20 Groups

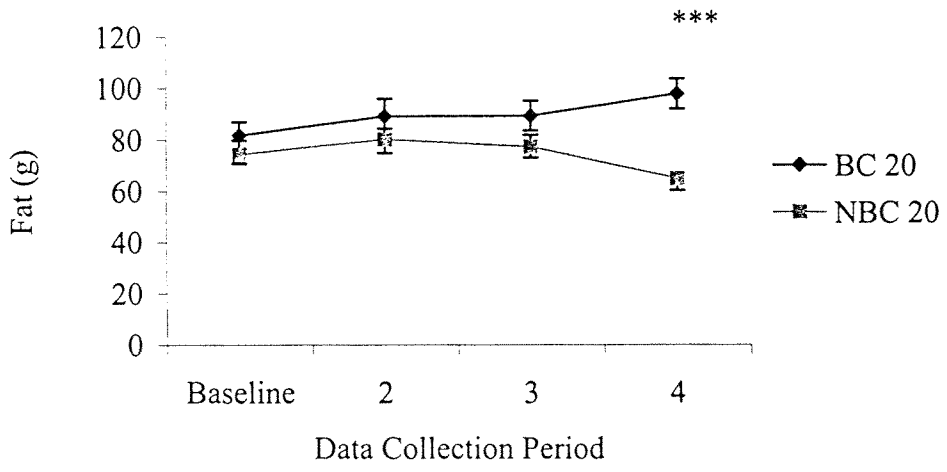


Figure: 6.3d Total Dietary Fat of the BC 20 and NBC 20 Groups
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

Total Dietary % Energy Fat of the BC 20 and NBC 20 Groups

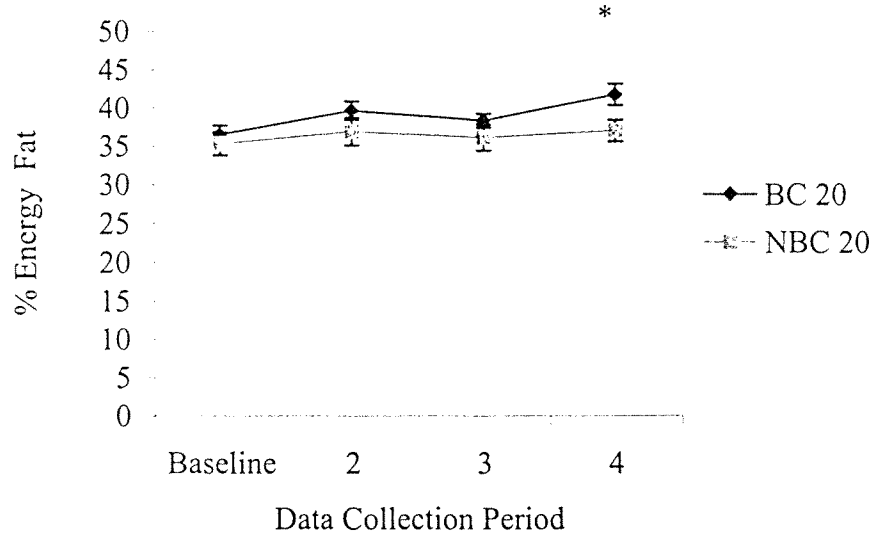


Figure: 6.3e Total Dietary % Energy Fat of the BC 20 and NBC 20 Groups
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

At data collections 2,3 and 4 dietary PUFA was higher for the BC 20 group than the NBC 20 group. This also affected % energy PUFA and % RNI PUFA. This is illustrated below in figures 6.3f-6.3g below.

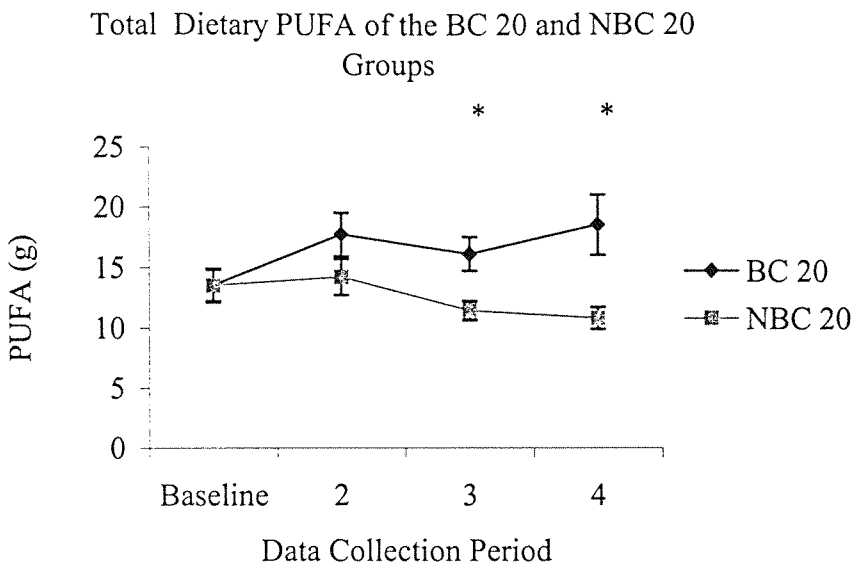


Figure:6.3f Total Dietary PUFA of the BC 20 and NBC 20
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

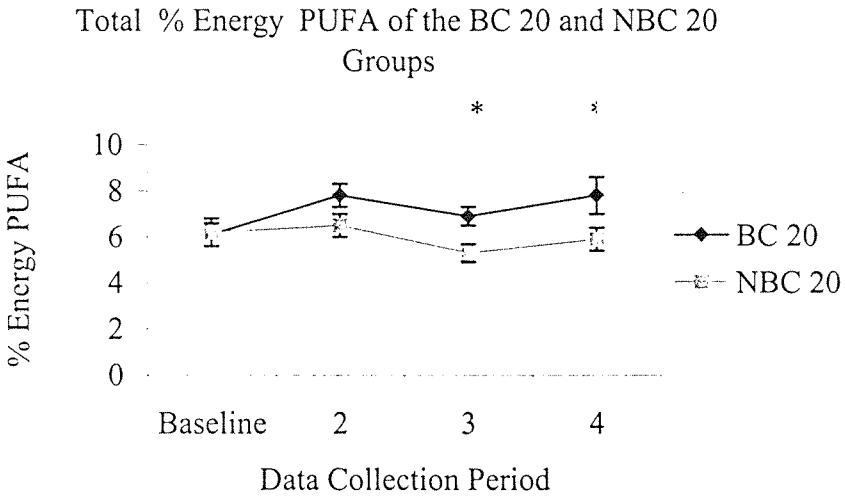


Figure:6.3g Total % Energy PUFA of the BC 20 and NBC 20 Groups
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

MUFA was higher in the diets of the BC 20 group also (see figure 6.3h below).

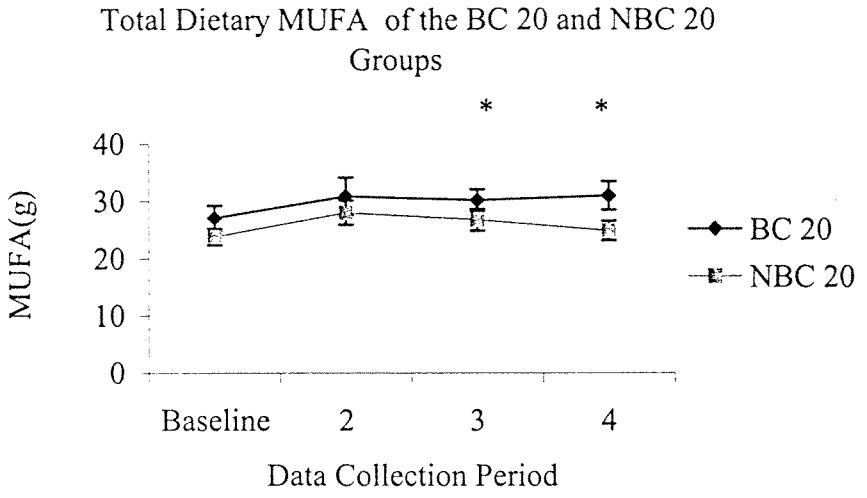


Figure:6.3 h Total Dietary MUFA of the BC 20 and NBC 20 Groups
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

The DRV of SFA for % contribution to food energy intake is 11%. Both groups showed an average of 14% energy from this fat when all data collection points were taking into consideration (see figure 6.3l). CHO intake was higher for the NBC 20 group at data collections 2 and 3 Percentage energy from CHO for total dietary intake was also higher in the NBC 20 group (see 6.3k below).

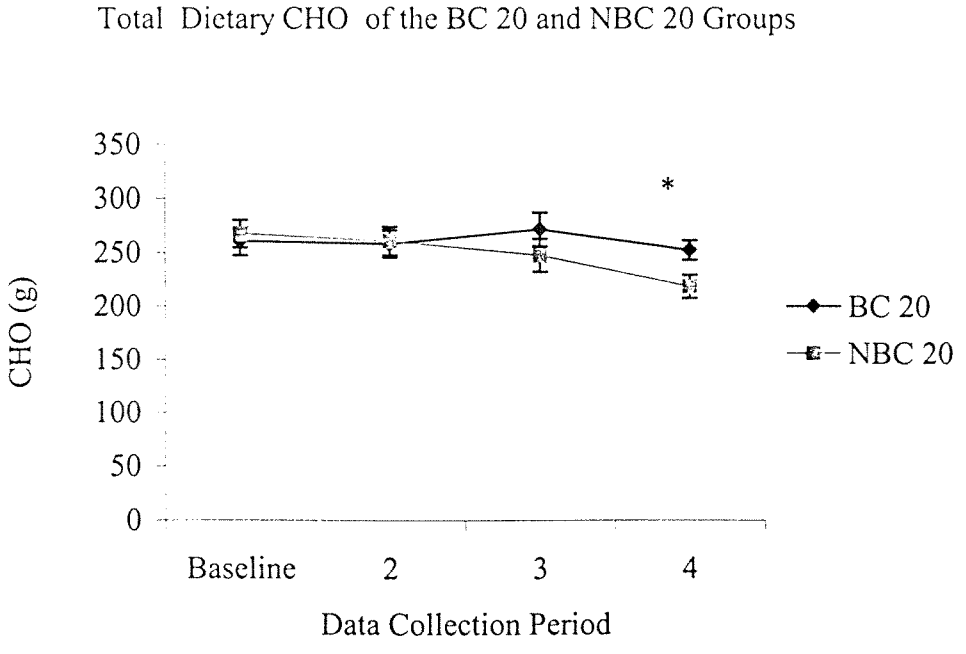


Figure: 6.3k Total Dietary CHO of the BC 20 and NBC 20 Groups

where * $p \leq 0.05$, ** $p \leq 0.01$ and *** $p \leq 0.001$

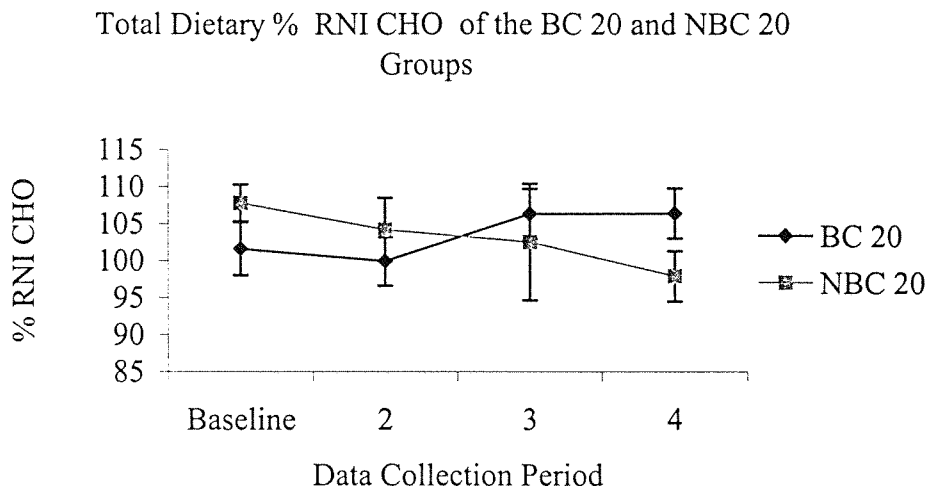


Figure:6.3l Total Dietary % RNI CHO of the BC 20 and NBC 20 Groups
where * $p \leq 0.05$, ** $p \leq 0.01$ and *** $p \leq 0.001$

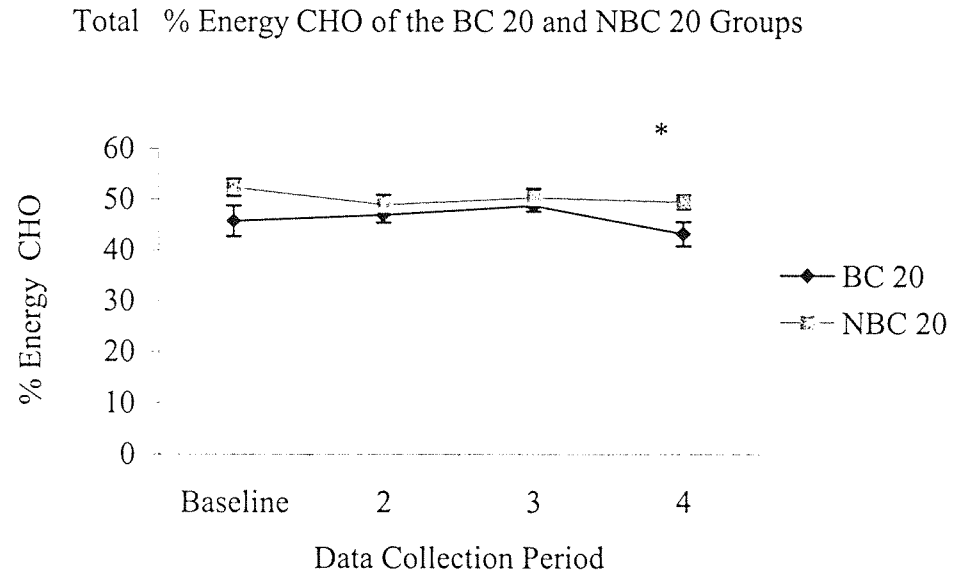


Figure: 6.3m Total % Energy CHO of the BC 20 and NBC 20 Groups
where * $p \leq 0.05$, ** $p \leq 0.01$ and *** $p \leq 0.001$

It is recommended that starch should provide 39% of energy. Both groups were below this recommendation (see figure 6.3n below), and the BC 20 were more deficient in this nutrient.

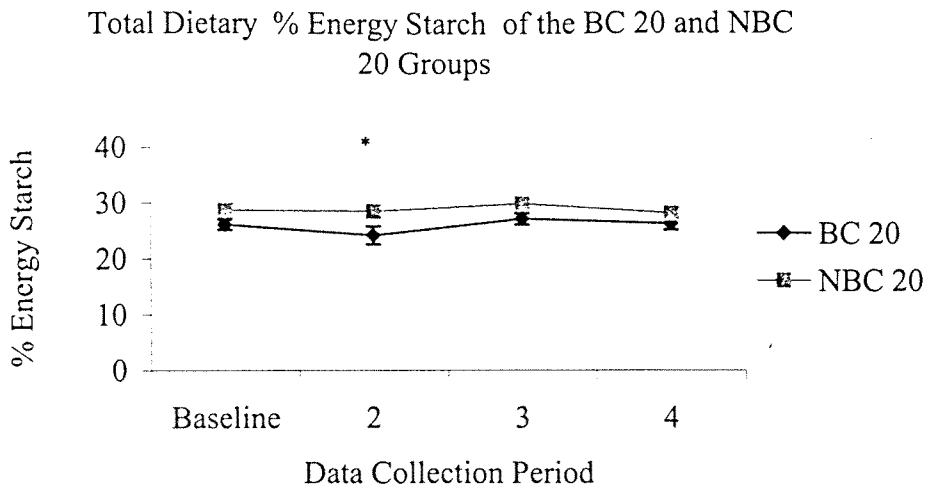


Figure:6.3n Total Dietary % Energy Starch of the BC 20 and NBC 20 Groups
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

The DRV for sugar is that it should provide no more than 11% of total energy. Referring to figure 6.4o below % energy from sugar was well above this for both groups.

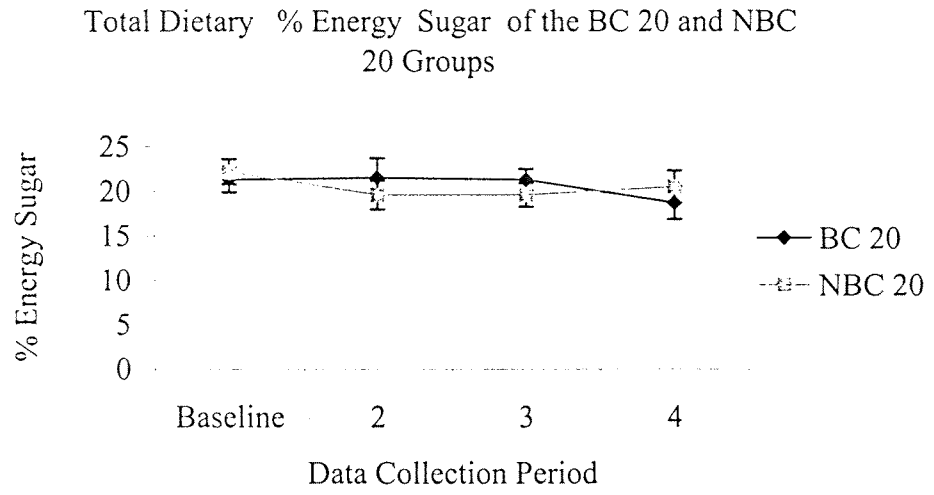


Figure: 6.3 o Total Dietary % Energy Sugar of the BC 20 and NBC 20 Groups
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

Dietary Ca intakes were higher and significantly so for the BC 20 group at data collection 2 , 3 as compared to the NBC 20 group. This difference between the groups is illustrated below in figure 6.3p Both groups were over the % RNI for Ca the BC 20 group were up to 40% over the RNI for this mineral.

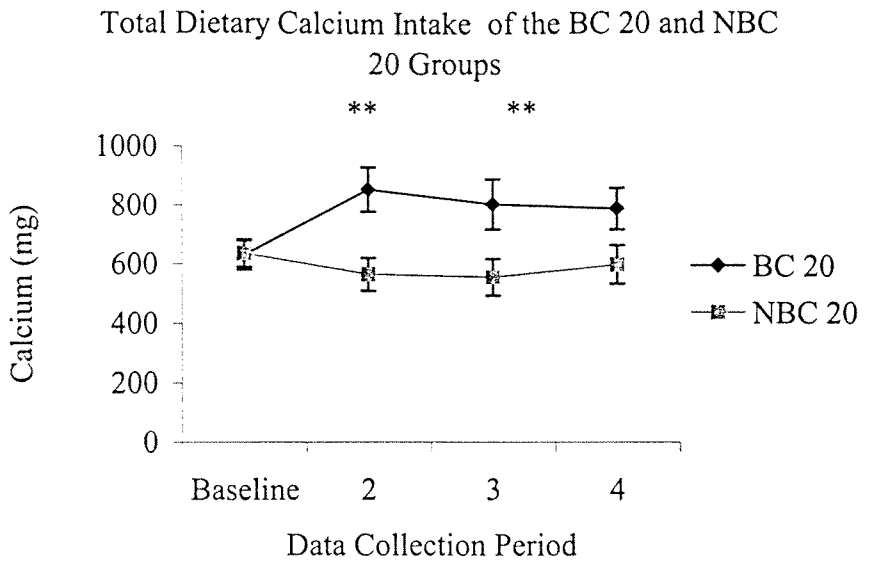


Fig: 6.4pTotal Dietary Calcium Intake of the BC 20 and NBC 20 Groups
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

Figure 6.4q and figure 6.4r illustrates the differences in daily vit C, % RNI vit C of both group and shows that at data collections 2,3 and 4 intakes were higher for the BC group.

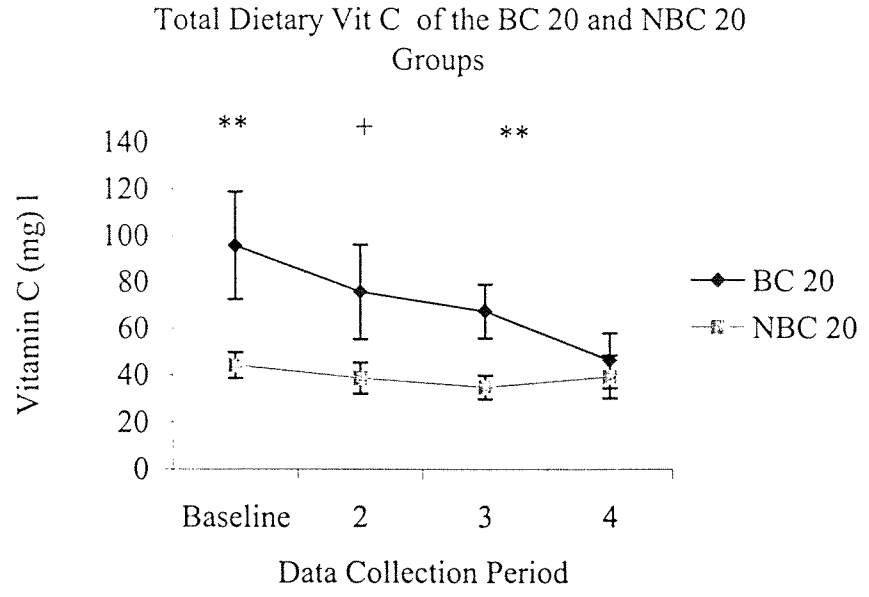


Figure: 6.4 q Total Dietary Vitamin C of the BC 20 and NBC 20 Groups
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

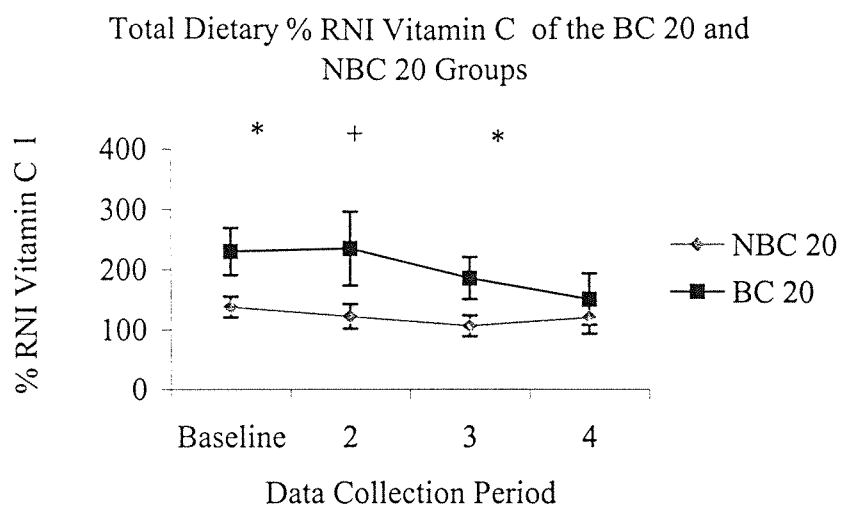


Figure:6.4rTotal Dietary % RNI Vitamin C of the BC 20 and NBC 20 Groups
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

6.3.3 Discussion

At both all 3 data collection periods including the baseline measurement the BC 20 group were consuming more calories than the NBC 20 group. There was a significant difference between the groups at data collection 4. This could be because the children in the NBC 20 groups were eating less calorific foods in the summer months. Whilst this might also have occurred in the BC 20 group the continued consumption of a cooked breakfast at the breakfast club might have an impact on total dietary intake. The NBC 20 group were eating more cereals and therefore less fat at the breakfast meal than the BC 20 group. One breakfast study has shown that preschool children who consumed less CHO (<50% of energy intake) or more fat (>35% of total intake) at breakfast showed poorer energy profile and poorer fat quality over their whole diet (Navia *et al.*, 1997). The breakfasts of the BC 20 group were higher in calories than the NBC 20 group (as discussed in chapter 6.2), and this suggests that the intakes at breakfast have an impact on total day intakes. Results of the Third National Health and Nutrition Examination Survey in the U.S (NHANES III) which looked the different types of breakfast on energy intake for the rest of the day showed that people who meat and eggs for breakfast at the highest daily energy intake (Cho *et al.*, 2003).

As illustrated in Figure 6.41 shows that the children were consuming the RNI or just above the RNI for calories at each data collection point. Another Scottish study which looked at energy and nutrient intake of 7-8 year old primary school children showed that calorie intake was close to the RNI (Ruxton *et al.,* 1996). Results of the NDNS show that 7-10 year old boys were achieving 91% of the RNI for calories whilst girls were getting 92% of the RNI for energy (NDNS, 2000).

The BC 20 group had a higher % energy from protein but this was only significant at baseline. There were no differences in breakfast types between the groups at baseline so we can deduce that protein consumption must have been greater from either lunch, snacks or dinner. As illustrated in figure 6.4c we can see that this effect disappeared after the commencement of the breakfast club where rolls filled with cooked meat were available. The fact that protein intakes were lower than the baseline measurements for this group indicates that protein intake at breakfast reduced protein intake at subsequent meals. Protein intakes were above the RNI for both groups. This was also the case in the study of Scottish primary schoolchildren (Ruxton *et al.*, 1996) and in 7-10 year old children in the NDNS (NDNS, 2000).

Dietary fat intakes were higher for the BC 20 group at all data collection periods and significant at data collection 4. The percentage energy for fat was also significant at data collection 4. The amount of fat in the breakfast meals was significantly higher at data collections 2 and 3 (see chapter 6.3). The fact that this difference did not exist when total diet was examined for these data collection periods implies that the BC 20 children (who consumed the higher fat breakfast) compensated for fat intake for the rest of the day. This would bean explanation for the similar total fat intakes of the BC 20 group who ate a significantly greater % of cooked breakfasts and the NBC 20 group who ate significantly greater amounts of cereal breakfasts. However the number of subjects for which dietary

information was obtainable for breakfast was greater than the completed diaries for total day intake . Therefore because there was missing data for total dietary intake we can not deduce how breakfast fat has affected total fat intake. This however will be discussed in the next chapter where the contribution of breakfast to total day intake is discussed and has therefore analysed the data for subjects completing the entire food diary.

Percentage energy from fat was above the recommended 35% of energy for both groups and was higher for the BC 20 group. Both groups were achieving over 100% of the RNI for fat. Data from the NDNS showed that children who were 7-10 years old were only slightly over the prescribed DRV and were gaining 35.9% of their energy from fat. The last national survey which looked at the diets of British school children in 1983 (The Diets of British School Children, 1990) showed fat intakes to be higher than the results of the NDNS this at all age ranges. The diets of the Scottish school children in the BC 20 and NBC 20 groups could be closer to the diets of the children in the 1983, reflecting more traditional patterns in Scotland.

At data collections 2,3 and 4 dietary PUFA was higher for the BC 20 group than the NBC 20 group. This also affected % energy PUFA and % RNI PUFA. This is illustrated below in figures 6.4g-6.4i below. In chapter 6.2 which explored the differences in breakfast intake of the BC 20 and NBC 20 groups there were significant differences for PUFA, % energy PUFA, % RNI PUFA. Whilst the total day dietary information is from smaller group of children through to lack of compliance of filling in the full diary we can postulate that intake of PUFA at breakfast (from the use of sunflower spread in the hot filled rolls) has affected total day intake of PUFA. This will be further examined in the next chapter. Ortega in his study of preschool children found that children who ate breakfasts which provided > 20% of daily total energy showed lower intakes of energy , proteins, fats, SFA, MUFA, PUFA and cholesterol, than those who ate a breakfast which had < 20% energy (Ortega, 1998). This will be explored for the BC 20 and NBC 20 groups in the next chapter.

Whilst increasing PUFA may have beneficial consequences in lowering HDL cholesterol (Mensink *et al.,* 1990), increasing any type of fat above the RNI should not be encouraged. The BC 20 group were above 100% of the RNI for this fat. Ruxton revealed that 5.3% of Scottish primary school children's energy came form PUFA (Ruxton, 1996). The BC 20 group obtained 6-8% of energy from this fat whereas the NBC 20 group obtained 6% of their energy from this fat. Data was collected for Ruxton's study in 1991 and the difference in energy intake from PUFA in the present study even at baseline could reflect the changing dietary habits over the last decade. However NDNS data shows that the mean % energy for PUFA for 7-10 year old children was 5.1% (NDNS, 2003). The NBC 20 group therefore have intakes of this fat closer to what can be considered to be a national average.

MUFA was higher in the diets of the BC 20 group also. This was also evident in the breakfasts of the BC 20 and NBC 20 groups. This implies again that breakfast intakes affect total day intakes. It is recommended that 13% of energy comes from MUFA and the BC 20 group were closer to this than the NBC 20 group . One of the schools used olive spread on the hot filled rolls on this increased MUFA intakes. Low coronary heart disease rates have been described in countries following a so called " Mediterranean diet". Whilst some of these countries do have high intake . Whilst the results discussed here could be used as evidence to support the use of olive spread rather than sunflower spreads at breakfast clubs in schools, perhaps more attention should be given to ensuring that the total fat of the breakfast is kept low.

The DRV of SFA for % contribution to food energy intake is 11%. Both groups showed an average of 14% energy from this fat when all data collection points were taking into consideration. Results of the NDNS show that children age 7-10 have 14.4 % of their energy from this fat (NDNS, 2003). Thus the present study reflects these findings. A

study looking at 7-8 year old children in Scotland showed that % energy from SFA was also 14% (Ruxton *et al.*, 1996).

CHO intake was higher for the NBC 20 group at data collections 2 and 3 and higher for the BC 20 at data collections 3 and 4. The BC 20 breakfast was greater in CHO all data collection periods because of the consumption of increased consumption of bread rolls and toast. The percentage of energy from CHO at the breakfast meal was greater in the NBC 20 group at data collection 2, 3 and 4 as shown in chapter 6.2. Percentage energy from CHO for total dietary intake was also higher in the NBC 20 group .This indicates that the higher % energy from CHO at breakfast can mean higher % energy from CHO for the entire day. This is was proved by Kirk (Kirk *et al.*, 1997) where consumption of cereal for breakfast increased CHO intake for the day and decreased fat intakes. Other research has also indicated that a high CHO breakfast can make a major contribution to a educed fat intake for the entire day (Crawley, 1993).

It is recommended that % energy from CHO is 50% and the NBC 20 group were closer to this recommendation. CHO has a role in maintaining a healthy diet and increasing CHO is the focus of healthy eating strategies. CHO is important for all age groups and especially children who have high energy requirements. It is required in the diet to prevent ketoacidosis and because there are substantial reasons why other sources of food energy should not provide more than a certain proportion of total food energy. If breakfast has an affect on the % of CHO intakes for the day, then it is legitimate to propose that a breakfast club should have nutritional guidelines to ensure that this nutrient is available at this meal in sufficient amounts.

The NDNS found that children aged 7-10 years old were getting 51.5% of their energy from CHO, whilst Ruxton's Scottish study showed that children had 50.5% of energy from this source. The NBC 20 group had a mean intake of 50.3% energy from CHO, whilst the BC 20 group had an average of 46.1%. This implies that a cooked breakfast may decrease % energy from CHO for the day, whilst a cereal breakfast may increase % energy from

CHO. CHO also has a role in weight management. Ortega found that obese children skip breakfast more often and eat less cereals compared to normal weight peers (Ortega *et al.*, 1998). The relationship and height and weight velocity will be further explored in between different breakfast types will be explored in chapter 9.2.

It is recommended that starch should provide 39% of energy. Both groups were below this recommendation and the BC 20 were more deficient in this nutrient. Ruxton's Scottish study showed that children obtained 32.8% of energy from this source.

The DRV for sugar is that it should provide no more than 11% of total energy The % energy from sugar was well above this for both groups. This is true also for the population investigated in the NDNS and the 1991 Scottish study (Ruxton, 1996). The amount of sugar *per se* was greater at all data collection points for the BC 20 group which reflects the high consumption of fruit juice and sweetened milkshakes in this group.Dietary Ca intakes were higher and significantly so for the BC 20 group at data collection 2 , 3 as compared to the NBC 20 group.. In chapter 6.2 which looked at the differences in the breakfasts of these 2 groups there was also a difference in Ca intake for the breakfast meal only. It can be concluded from this that Ca intakes at breakfast can affect intakes for the entire day. Ortega also found that the intake of milk products and Ca intakes at breakfast correlate with he consumption of these foods in the whole diet (Ortega *et al.*, 1998). Whilst the total daily intake of milk products and Ca did not depend solely on breakfast intake, the research showed that subjects with the greatest intakes at breakfast also showed the greatest intakes over the rest of the day.

It is of prime importance to monitor the intake of milk products and Ca in young and adolescent children to meet the high nutritional needs associated with growth and to safe-guard health later in life (Agostoni *et al.*,1994). In the NDNS of young people, 15% of girls and 12% of boys reported not drinking milk (Buttriss, 2002). About 25% of bone mass is acquired during adolescence (Buttriss, 2002) and the velocity of bone growth doubles in adolescence and at peak times the skeleton may be taking up 600mg of Ca per

day (Martin *et al* 1997). It is therefore crucial that younger children such as those examined in this research have eating habits which will facilitate this high Ca requirement when they start puberty. It was likely that a few children in this group had begun the onset of puberty (although this was not measured), since the 97th percentile of girls will have started puberty approximately by the age of 9 years 1 month (Growth and Development, British Longitudinal Standards)[11] and the age for boys the age for the onset of puberty for the 97th percentile is approximately 9 years and 8 months.

Whilst both groups were over the % RNI for Ca the BC 20 group were up to 40% over the RNI for this mineral. Requirements of individual children are dependable on many factors including stage of growth and activity levels. Therefore whilst the NBC 20 appear to have adequate amounts of this mineral it is possible that some children with particularly high Ca needs may have benefited from an increase in Ca consumption. In fact the NDNS revealed that 1 in 8 boys and 1-4 girls aged 11-14 years have Ca intakes below the lower RNI (NDNS, 2000).

The BC 20 group had higher Ca intake due to a high consumption of milk or milkshake as a drink at the breakfast meal. Many children drank two 250 ml cartons (which were available at the breakfast club at a subsidized cost). It is highly probable that they drank more milk at the breakfast club than they would have had at home. Whilst this is to be encouraged, the other constituents of the average breakfast club meal should be taken into consideration bearing in mind its possible effects on total day intake. Fat intake at breakfast has been shown to have an affect on total intake for the day and so it may be more beneficial to offer foods at the breakfast club which promote the intake of important nutrients, i.e. Ca in milk but also ensure that the meal is in line with healthy eating advice. Since eating breakfast cereal with milk is an effective way to increase Ca intake (Nicklas *et al.*, 1998), perhaps a breakfast club should offer this food with milk as a drink in an effort to comply both with the recommendations for healthy eating and to ensure high Ca intakes. It was also noted that 5-12 year olds who regularly omitted breakfast had lower

daily intakes of Ca as compared with children who consumed breakfast cereals on a regular basis (Morgan *et al* 1981).

Children who were classified as high cereal eaters (6-7 times a week) in one Scottish study had higher daily Ca intakes than moderate and low cereal eaters (Ruxton, 1996). Whilst the present study shows the opposite in that the children in the BC 20 children who ate more cooked breakfasts had higher daily Ca intakes, this phenomenon would not be a likely event if the children were to continue eating hot filled rolls at home. The high consumption of milk was likely to be due to its low cost and high availability rather than habit by the children. The food diaries exposed that for both groups at baseline and for the NBC 20 group at data collections 2,3, and 4 diluting juice, coffee and tea was a popular drink for this group of children. Drinking more than one cup of tea per day was associated with almost double the odds of low iron status amongst girls in the NDNS (Gibson , in press) and since the tannins in tea lower the absorption of key vitamins this is something that should be addressed as regards to breakfast practices at home.

When the breakfast meals of the BC 20 and NBC 20 group were explored there was a difference in the in vit C (mg) % RNI vit C. The BC 20 group had significantly greater vit C and % RNI vit C from the breakfast meal than the NBC 20 group at baseline and data collections 2, 3. There was a trend for this also at data collection 2. Figure 6.4v illustrates the difference in daily % RNI vit C. The difference at baseline between the groups is also evident for the entire day. This would imply that the intake of vitamin C at breakfast at baseline has contributed to the intake for the day. The trend that exists at data 2 also reflects the trend for a higher vit C intake and % RNI vit C at breakfast, again implying that the breakfast meal contributes significantly to total day intake. The contribution of breakfast to total day intakes will be further explored in chapter 6.5. It is interesting to note that even at baseline the BC 20 group had higher intakes of vit C. Further analysis of the diaries show that this group drank greater amounts of fresh fruit juice at breakfast than the

NBC 20 group. This habit was thus unchanged for this group by the introduction of a breakfast club at school.

The undisputed roles of vit C is to prevent scurvy and wound healing. It also assists in the absorption of non-haem Fe, and because of its potential for reaction with destructive free radical containing oxygen, it is an important antioxidant (DRVs For Food Energy and Nutrients for the UK, 1990). The BC 20 group had more than 150% of the RNI at all data collection points. There are only risks associated with very high intake (grams). In this low fruit and vegetable eating group of children a high intake of fruit juice should be encouraged as a means to getting the essential micronutrient. Analysis of the NDNS showed that fruit juice was the single greatest vit C contributing food for young people (NDNS, 2000).The Scottish research in 1991 showed that high cereal eaters had higher intakes of vit C (Ruxton, 1996).

6.4 The Contribution of Breakfast to Total Dietary Intake

Dietary intake was measured with a 3-day estimated diary as described in chapter 2.3. The mean values of total nutrient intake for the 3 days has been discussed in the previous chapter (chapter 6.4). The mean values of nutrient intake from the breakfast meal only for the 3 days have been discussed in chapter 6.1. In this chapter nutrient intakes at breakfast were examined as a percentage of total day intakes as follows:-

$$\frac{\text{Mean of nutrient X at breakfast}}{\text{Mean of nutrient X for the total Day}} \times 100\ \% = \text{contribution of breakfast to total daily intake (\%).}$$

The purpose of this chapter is to:

1) investigate the contribution of the breakfast consumed by BC 20 and NBC 20 group to total dietary intake at baseline, data collection 2, 3 and 4.

Table 6.4a Number of Subjects in the BC 20 and NBC 20 Group for the Contribution of Breakfast to Daily Intake Analysis

	Baseline	Data Collection 2	Data Collection 3	Data Collection 4
BC 20	16	11	13	13
NBC 20	20	17	13	16

Table: 6.4b Subject Characteristics of the BC 20 and NBC 20 Group for the Contribution of Breakfast to Daily Intake Analysis

	BC 20	NBC 20
Baseline		
Age	9.4(± 0.3)	9.8(± 0.2)
Gender	7F:9M	10F:10M
Data Collection 2		
Age	9.4(± 0.3)	9.9(± 0.3)
Gender	5F:6M	8F:9M
Data Collection 3		
Age	9.7(± 0.4)	9.7(± 0.4)
Gender	5F:8M	5F:8M
Data Collection 4		
Age	9.7(± 0.4)	10.4(± 0.4)
Gender	5F:8M	8F:8M

6.4.1 Breakfast at Baseline – October/November 2000

The Contribution of Breakfast of the BC 20 and NBC 20 Groups to Daily Macronutrient Intakes At Baseline

At the baseline measurement there was no difference in the contribution of breakfast to total daily intakes of the 2 groups. Breakfast provided 12.6±0.8% and 13.5±1.1% and calories for the entire day. Fat from the breakfast meals contributed to 7.8±1.4% 10.6±2.8% of total fat intake for the day for the BC 20 and NBC 20 respectively. Referring to table 6.5 below breakfast provided approximately 16% of CHO for both groups and 19% of sugars. As illustrated in table:6.5c below the breakfast meal also gave the children 9.5±1.4%and 11.5±3.6% of their daily fibre intake.

The Contribution of Breakfast of the BC 20 and NBC 20 Groups to Daily Micronutrient Intakes At Baseline

Breakfast provided over 20% of the total day intake of calcium and iron for both groups. The breakfast consumed by the BC 20 group contributed a greater % of vit C to the total daily intake. As shown in table 6.1 below the BC 20 breakfast contributed to 16.3±5.3% of vitamin C whereas the NBC 20 breakfast provided only 6.9±2.5%. As shown in table 6.5d below the breakfast meal provided 22.9±4.0% and 15.6±3.0% of vit A to total dietary intake. Breakfast provided over 25% of the daily intakes of the B vitamins and over 40% of vitamin D for both the BC 20 and NBC 20 groups.

6.4.2 Summary of the contribution of breakfast to daily intakes over data collections 2,3 and 4

The breakfast eaten by the BC 20 group contributed 12-20% of calories for the day, whilst the breakfast of the NBC 20 group provided 12-14% of calories As illustrated in figure 6.5a below there was a significant differences between the groups for the contribution of calories at breakfast at data collections 2 and 3 after the start of the breakfast club.

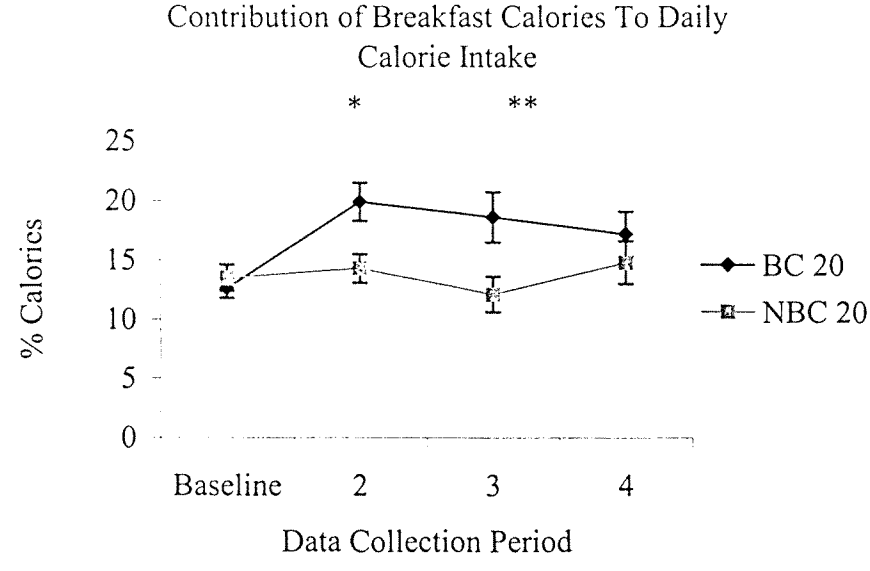


Fig:6.4a Contribution of Breakfast Calories To Daily Calorie Intake
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

Breakfast contributed 12-16% of protein intake for the day in the NBC 20 group and 12-18% for the BC 20. As depicted in figure 6.5b below this difference was significant at data collection 3.

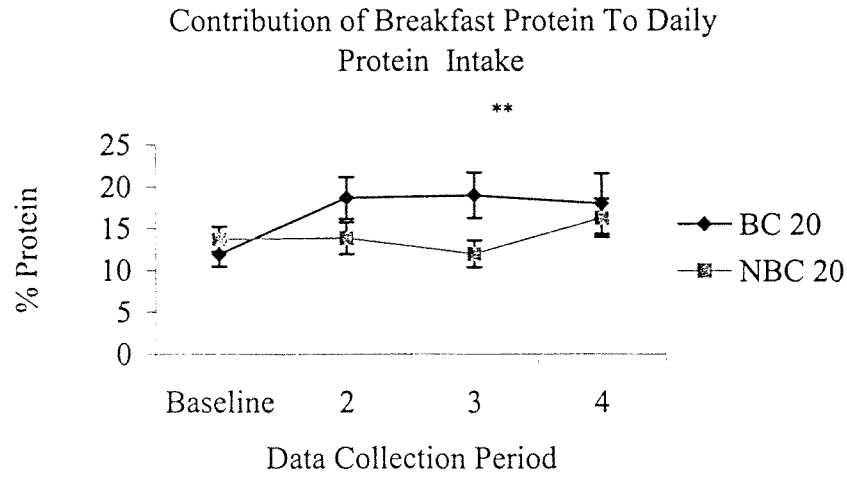


Figure: 6.4 b Contribution of Breakfast Protein To Daily Protein Intake
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

As represented in the graph below breakfast provided 7-15% of daily fat for the NBC 20 group whilst it provided the BC 20 group with 10-16%.

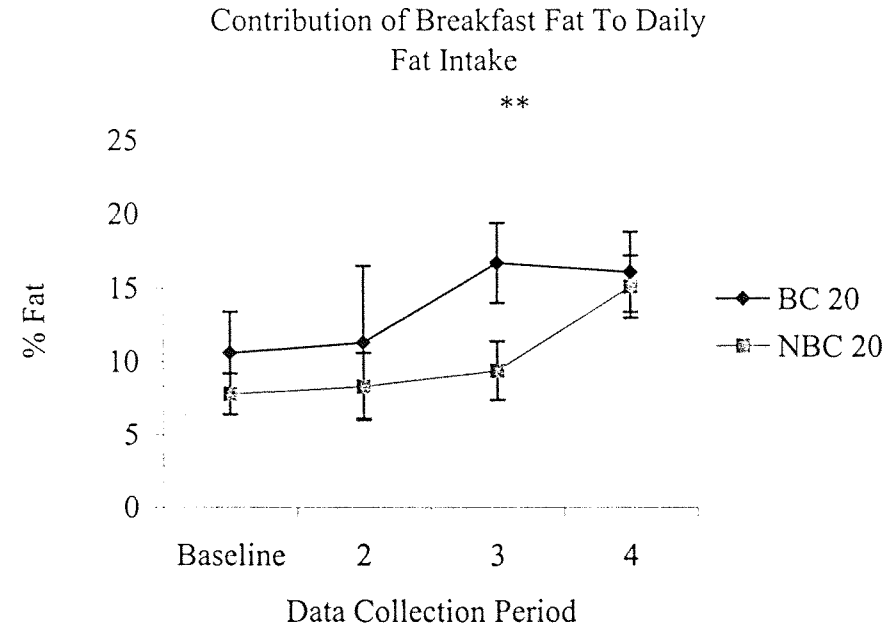


Figure: 6.4c Contribution of Breakfast Fat To Daily Fat Intake
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

Illustrated below in figure 6.4d is the contribution of the breakfast meal to daily PUFA intakes, which demonstrates that PUFA intakes at breakfast significantly contributed to intakes for the day and the difference in breakfast types will affect this. The same was also evident for MUFA (see figure 6.4e).

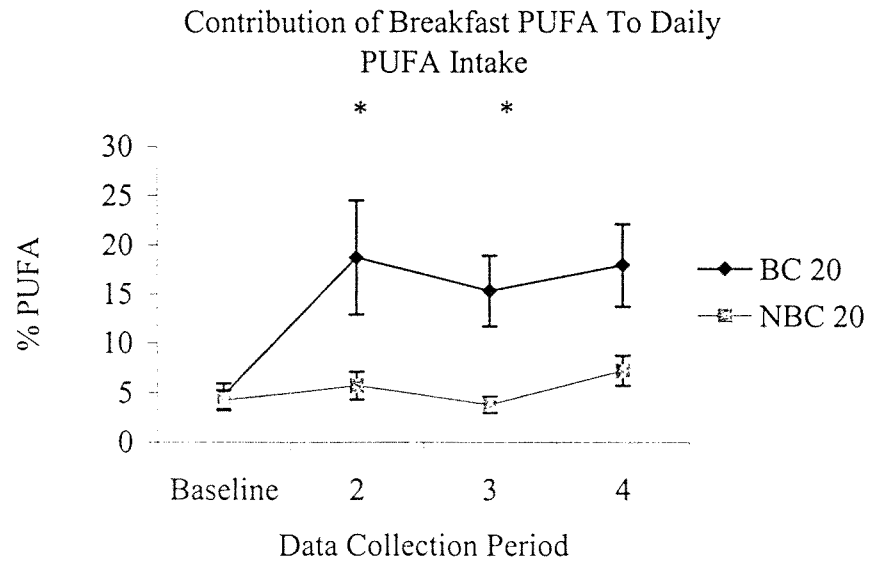


Figure: 6.4d Contribution of Breakfast PUFA To Daily PUFA Intake
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

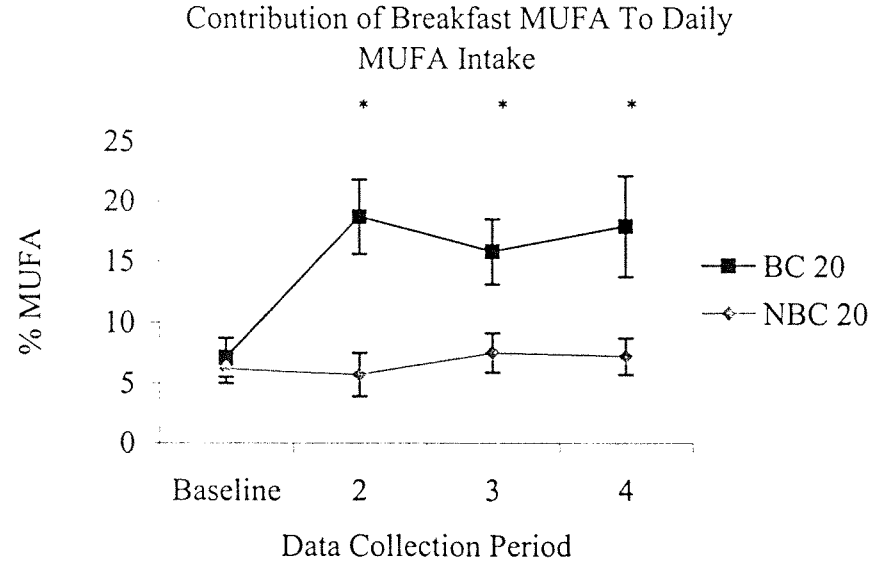


Figure: 6.4e Contribution of Breakfast MUFA To Daily MUFA Intake
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

There was a difference between the group in the contribution of SFA at breakfast to total day SFA. At baseline the groups were matched as shown below in figure 6.5f however

after the start of the breakfast club the contribution that the breakfast meal made to total day intakes was higher in the BC 2 group than the NBC 20 group and significantly so at data collection 3.

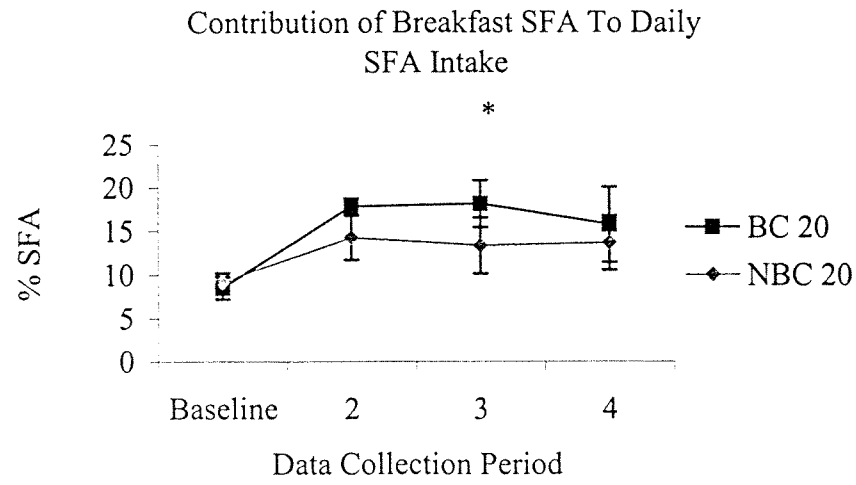


Figure:6.4 f Contribution of Breakfast SFA To Daily SFA Intake
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

After the commencement of the breakfast club the contribution of CHO from breakfast to total CHO intake was 20.4% for the BC 20 group and 16.1% for the NBC 20 group.

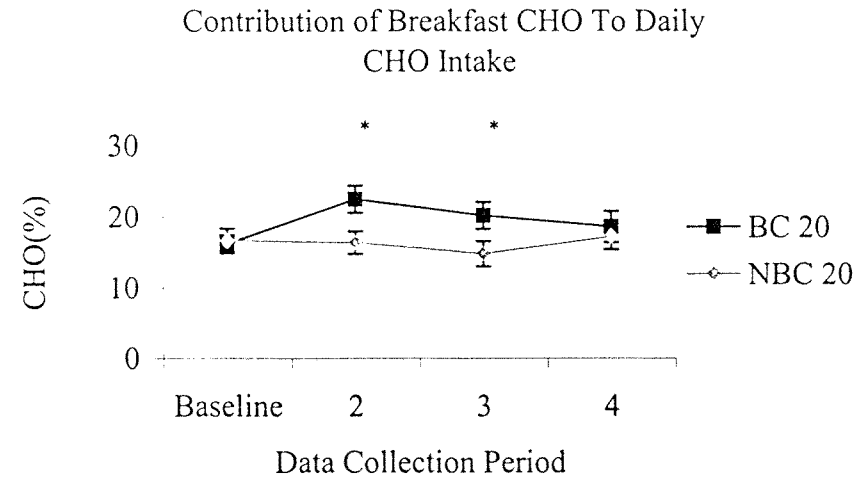


Figure:6.4 g Contribution of Breakfast CHO To Daily CHO Intake
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.0$

Starch (g) *per se* was higher in the breakfasts of the BC 20 groups (see figure 6.5h) but % energy from starch was higher in the NBC 20 groups at all data collection periods (except data collection 4).

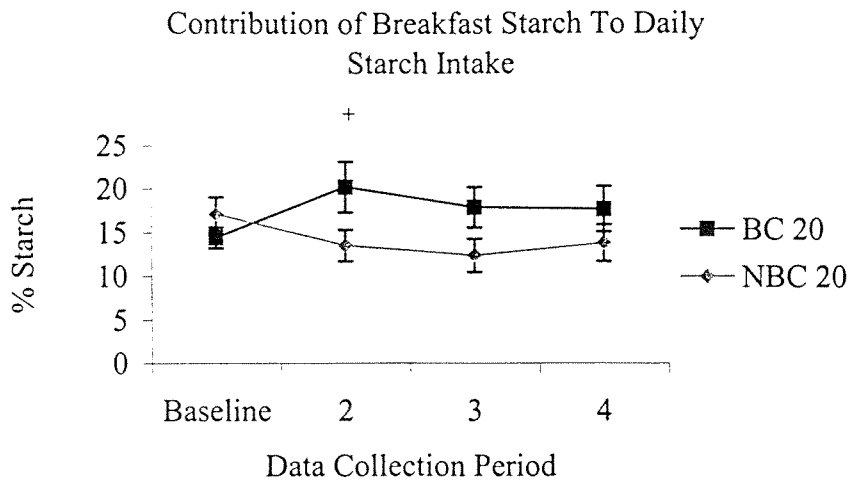


Figure:6.4h Contribution of Breakfast Starch To Daily Starch Intake
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

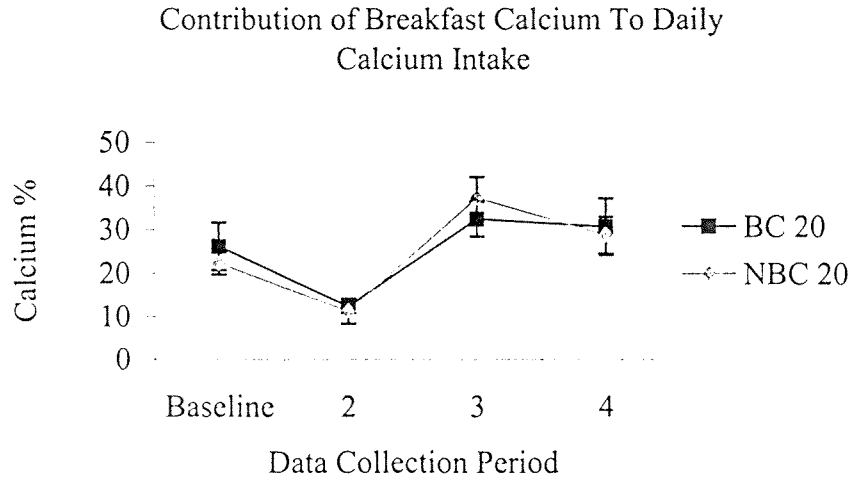


Figure: 6.4 i Contribution of Breakfast Calcium To Daily Calcium Intake
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

There were no differences between the groups in the contribution of the breakfasts to Fe intakes(see figure:6.5i).The breakfast meal of the BC 20 group was contributing a greater % of vit C to the diet, as illustrated in figure 6.4j.

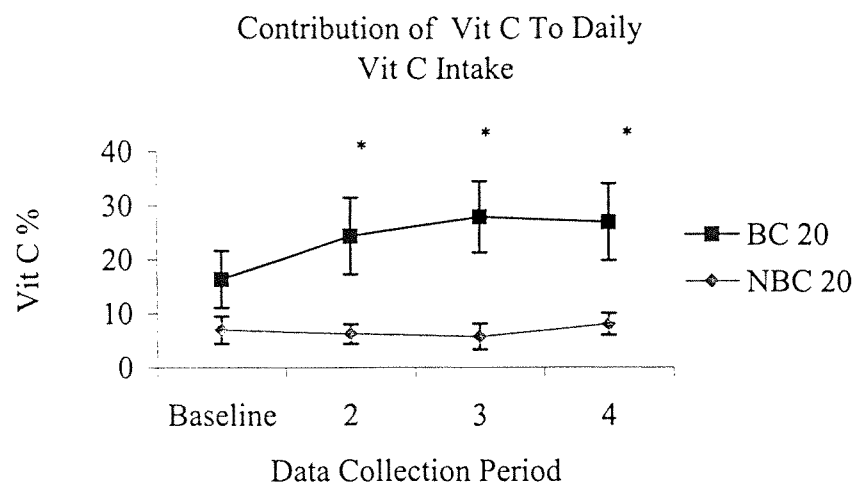


Figure: 6.4j Contribution of Vit C To Daily Vit C Intake

where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

In general the NBC20 breakfast contributed a higher (40%) of the B-vitamins to total daily intakes than the BC breakfast (30%). Breakfast was an important contributor of intakes of vit D for the day. The breakfast meal contributed 40-50% of total day intakes for both groups.

6.4.3 Discussion

The breakfast eaten by the BC 20 group contributed 12-20% of calories for the day, whilst the breakfast of the NBC 20 group provided 12-14% of calories. There was a significant differences between the groups for the contribution of calories at breakfast at data collections 2 and 3 after the start of the breakfast club. This difference also existed at these data collection periods when the difference in calories of the breakfast meals were investigated (chapter 6.1).

Health care professionals recommend that breakfast should provide 20% of calories and nutrients for the day (Gibson and O'Sullivan, 1995) and so the BC 20 club were closer to this guideline after the breakfast club had opened. In her 1991 study of 136 Edinburgh school children Ruxton found that breakfast contributed 14% of energy (Ruxton, 1996). This finding is in line with the 12-14% energy intake at breakfast for the NBC 20 group. Livingstone found that breakfast supplied 6% of energy intake in 5-9 year olds, while there

was a 20% contribution to calories for 8 year olds (Margarey *et al.*, 1987) and 16% for 10-15 year olds by Spyckerelle *et al.*, (1992). Morgan *et al.*, reported that children aged 5-12 years consumed 18% of their calories at breakfast (Morgan 1986).

Greer revealed that children 4-5 years of age consumed 22% of their calories at breakfast if they ate cereal a and 24% if their breakfasts did not contain cereal (M.S Thesis, 1990). The lower contribution of calories from the cereal breakfast is evident in the present study also.

Breakfast contributed 12-16% of protein intake for the day in the NBC 20 group and 12-18% for the BC 20. This difference was significant at data collection 3. Protein intakes were higher in the BC group because more children were consuming a cooked breakfast (sausage, bacon, black pudding ,egg filled roll or cheese toastie) at this point than the NBC 20 who were consuming more cereal. In the NDNS of young people cereal and cereal products contributed to just over quarter of protein intakes (Buttriss, 2002). Ruxton's breakfast analysis found that this meal contributed 16 % of protein intakes, whilst Navia study of children aged 2-6 years found that breakfast contributed to 13.5% of total protein intake. Morgan also found that breakfast provided children with 16% of their protein intake (Morgan *et al.*, 1986).

Breakfast provided 7-15% of daily fat for the NBC 20 group whilst it provided the BC 20 group with 10-16%. The dietary recommendation of the COMA report (DoH, 1994) emphasises reducing fat intake. Reducing the % of fat at the breakfast meal therefore may play a part in helping to reduce fat intakes for the day. A multivariate analysis by Gibson *et al.*, (1992) of the DoH's survey of the Diets of British schoolchildren identified one pattern of food consumption that was correlated with a high percentage energy from fat. This pattern was characterised by a high intake of butter and white bread, and a low intake of breakfast cereals and milk, suggesting that in children breakfast consumption may be a positive indicator of a low fat diet (Gibson *et al.*, 1995). In chapter 6.4 the % energy from

fat for the entire day has been explored and the % energy from fat for the BC 20 group after the commencement of the breakfast club was 39.8%. For the NBC 20 group % energy from fat for the day was 36.6%. In chapter 6.1 the % energy of fat in the breakfast meal was investigated and the average % energy of fat for data collections 2,3 and 4 was 30.8% whilst it was 24.4% for the NBC 20 group. Therefore there is evidence to suggest that the % energy of fat at breakfast can have an impact on % energy from fat for the day and depending on the type of breakfast eaten the fat at that meal will have an impact on the contribution of fat intake for the day. In an analysis of the NDNS Gibson found that breakfast cereals alone make a low contribution to fat intake (1%) but a good contribution to CHO intake (11% in boys and 8% in girls).

One of the major findings of this investigation was that the use of sunflower and olive spreads at the breakfast club influenced not only breakfast intakes of PUFA and MUFA but also intakes of these fats for the entire day. PUFA intakes at breakfast significantly contributed to intakes for the day and the difference in breakfast types will affect this. The same was also evident for MUFA.

There was a difference between the group in the contribution of SFA at breakfast to total day SFA. At baseline the groups were matched however after the start of the breakfast club the contribution that the breakfast meal made to total day intakes was higher in the BC 20 group than the NBC 20 group and significantly so at data collection 3. Whilst the % energy from SFA for the entire day was not different for the BC 20 and NBC 20 groups, a high contribution of SFA from breakfast should not be encouraged.

Whilst the % energy of CHO was higher for the NBC 20 group for the breakfast meal and for total day intakes, the CHO in the breakfast of BC 20 group contributed a greater % of CHO to total day intakes. This was because there was more CHO *per se* in the BC 20 breakfast due to the consumption of white bread rolls and toast. Research has shown that a breakfast which has a high % energy CHO can make a major contribution to a reduced fat intake for the day (Crawley, 1993, Sommerville *et al.*, 1993 and Gibson *et al.*, 1995).

Whilst the BC 20 group had higher CHO intakes *per se* as compared to the NBC 20 groups the % energy CHO of these breakfast was lower than the NBC 20 groups and the fat was higher. As discussed the fat intakes of the NBC 20 group were lower than that of the BC 20 and so we can conclude that this study is in agreement with the aforementioned studies. After the commencement of the breakfast club the contribution of CHO from breakfast to total CHO intake was 20.4% for the BC 20 group and 16.1% for the NBC 20 group. Magarey found that breakfast provided 19% of CHO in the study looking at breakfast intake of 11 year olds (Magarey *et al.*, 1997) whilst Ruxton found that breakfast provided 7-8 year old children with 18% of their CHO intake.

The breakfast meal contributed a greater % of starch to the diets of the children of the BC 20 after the start of the breakfast club. However % energy from starch for the day was higher in the NBC 20 group when this was explored in chapter 6.4. Starch (g) *per se* was higher in the breakfasts of the BC 20 groups but % energy from starch was higher in the NBC 20 groups at all data collection periods (except data collection 4).

The BC 20 breakfast contributed a greater % of sugar to the diet. This may be attributable to high intake of fruit juice and sweetened milkshakes. There was small percentage (1 %) of children in the NBC 20 group who were consuming 'unsuitable foods' at breakfast i.e. confectionary and fizzy drinks and this will have an impact of raising sugar intakes in this group. There were no children however at the breakfast club still eating confectionary at breakfast

The breakfast meal contributed an average of 10.8% of the fibre consumed in a day by the BC 20 group and 10.1% for the NBC 20 group. Breakfast cereals were found to provide 10% of the fibre in the diets of young people in the U.K (NDNS, 2000) and so the findings illustrated here for the NBC 20 group also echo the analysis of the national survey.

Calcium intakes at the breakfast meal were higher for the BC 20 group. Calcium intakes for the total day were also higher in the BC 20 group as compared to the NBC 20 group.

However when the contribution of Ca to daily intakes were examined there were no differences between the groups. As discussed previously the high intakes of Ca at breakfast by the BC 20 group was due to the high consumption of milk. The Ca intake of the NBC 20 group is mainly due to the consumption of milk with cereals. The fact that there is little difference in the contribution of these 2 groups breakfasts to total Ca intake implies that does in fact encourage milk consumption and supports the research of Nicklas who postulated that eating cereal breakfast with milk is an effective way to increase Ca intake in children and teenagers (Nicklas *et al.,* 1998).

The BC 20 breakfast contributed 25.1% of Ca whilst the NBC 20 breakfast provided 25.7% of this mineral. Ortega found that the intake of milk products and Ca intakes at breakfast correlate with he consumption of these foods in the whole diet (Ortega *et al.,* 1998). Whilst the total daily intake of milk products and Ca did not depend solely on breakfast intake, the research showed that subjects with the greatest intakes at breakfast also showed the greatest intakes over the rest of the day. Breakfast contributed to 22% of the Ca intake in the 1991 study of Scottish primary school children (Ruxton *et al.,* 1996).

There were no differences between the groups in the contribution of the breakfasts to Fe intakes. After the opening of the breakfast club the contribution of breakfast to total Fe intake was 22.4% in the BC 20 group whilst it was 20.9% in the NBC 20 group. Intakes of Fe in the BC 20 group were marginally greater due to the intakes of meat products at the breakfast meal. The source of Fe in the NBC 20 group was due to the fortification of Fe in cereal. Fortified breakfast cereals provide 26% total Fe intakes among young people (NDNS, 2000). They are the single biggest source of Fe (26%) in the young persons diet, providing more iron than meat ad meat products (13%), breads (13%) or vegetables (17%) (NDNS, 2000). Nutritional anaemia is one of the mot common diet related deficiency disorders (Buttriss, 2002) and young people are particularly vulnerable to Fe deficiency (DoH, 1991). In the NDNS of young people , 13% of all boys and 14% of all girls had low

Fe stores (Buttriss, 2002). Therefore it is of major importance that children receive enough of this mineral. Fe intake at breakfast is therefore essential.

The breakfast meal of the BC 20 group was contributing a greater % of vit C to the diet. In chapters 6.1 and 6.4 where difference between the breakfast meals and that of the total were examined these differences also existed. The NDNS found that 1 in 5 children had no fruit during the week of the study. The children in this study were also low consumers of fruit. From this we can put forward that consumption of fresh orange juice at the breakfast should be encouraged, and that the provision of this at the breakfast club was a positive step towards improving the nutritional status of the school children.

There were no significant different between the group for the contribution of the breakfast meal to daily intakes of vitamin A. However the contribution of vit A by the BC 20 breakfast group was still greater. The source of this vit A was fortified margarine. The NBC 20 group was below the RNI for this vitamin and so whilst the use of fortified margarine at the breakfast club should be monitored to ensure that overall % energy from fat is not excessive fortification of vit A has improves the vit A status of the breakfast club children.

Breakfast was an important contributor of intakes of vit D for the day. Intakes of vit D might have been expected to be much higher in the BC 20 group after the commencement of the breakfast club because of the use of fortified margarine. However the breakfast meal contributed 40-50% of total day intakes for both groups.

7.1 Cognitive Performance

Cognitive performance of the breakfast club 20 (BC 20) and non-breakfast club 20 (NBC 20) were explored. The BC 20 group refers to the 20 subjects who stayed in the breakfast club group throughout the study (i.e. at data collection periods 2, 3 and 4) and the NBC 20 group were the 20 subjects who had their breakfasts at home. These 2 groups have been matched by age, gender, and BMI (refer to Chapter 2) and no differences were found with the groups at baseline. This has allowed for a longitudinal analysis of the data.

Cognitive performance as discussed in chapter 1 refers to short-term memory auditory memory, attention and mental computation and reasoning. This was measured using subtests from the Wechsler Intelligence Scale for Children-III^{uk} (WISC-III^{uk}). The rationale regarding the choice of this psychological test have also been discussed in detail in chapter 1.

The subtests of this test that were used were:-

1) Digit Span where the subjects recalled a series of items in forward and reverse order as a test of short-term auditory memory.

2) Coding where subjects replaced digits with symbols and this test is the discrimination of memory and visual pattern stimuli. This test examines vigilance also known as attention.

3) Arithmetic which measured mental computation and concentration. This tests examines reasoning.

The Arithmetic and Digit Span scores have also been added together and converted to give the Freedom from Distractibility Index (FDI) which has been used as a clinical indicator of Attention Deficit Hyperactivity Disorder (ADHD). The meaning of the FDI has been the topic of extended debate (Dockrell, 1992) and has been discussed in

detail in chapter 2. FDI scores of the BC 20 and NBC 20 group at data collection 2,3 and 4.

Cognitive function was measured at baseline before the commencement of the breakfast club. After the breakfast clubs opened in 2 of the schools there were 3 subsequent measurements at approximately 6 weeks apart. These data collection periods are shown below as data collection 2, 3 and 4. Scores from girls and boys have been represented together since population norms and validation samples are not divided by gender.

The raw scores of the Digit span, Coding and Arithmetic subsets of the WISC-III^{uk} have been age scaled and the results of the BC 20 and NBC 20 at baseline and data collection 2, 3 and 4. The scores from the BC 20 and NBC 20 group were compared using independent t-tests and no difference were found between the groups .

Scores at Data Collection Periods 2,3 and 4 Compared to Baseline

Paired t-tests were carried out between baseline measurements and scores at data collection 2, 3 and 4 respectively for BC 20 and NBC 20 groups. The differences between baseline measurements and subsequent data collection periods are given have below.

The purpose of this chapter therefore is to examine the difference in cognitive performance scores of the BC 20 and NBC 20 groups by comparing their baseline scores to scores at data collections 2,3 and 4.

Table 7.1a Number of Subjects in the BC 20 and NBC 20 Group for the Contribution of Breakfast to Daily Intake Analysis

	Baseline	Data Collection 2	Data Collection 3	Data Collection 4
BC 20	18	12	15	17
NBC 20	20	20	20	16

Table: 7.1b Subject Characteristics of the BC 20 and NBC 20 Group for the Contribution of Breakfast to Daily Intake Analysis

	BC 20	NBC 20
Baseline		
Age	9.5(± 0.2)	9.6(± 0.3)
Gender	7F:11M	10F:10M
Data Collection 2		
Age	9.6(± 0.3)	9.8(± 0.3)
Gender	3F:9M	10F:10M
Data Collection 3		
Age	9.8(± 0.3)	10.1(± 0.3)
Gender	6F:9M	10F:10F
Data Collection 4		
Age	10.1(± 0.3)	9.9(± 0.2)
Gender	6F:11M	10F:6M

7.1.1 Cognitive Functions Scores at baseline compared with scores at data collection 2,3 and 4

Table 7.1c Summary Table of the Cognitive Performance Score Improvements from Baseline To Data Collection 2,3 and 4 for the BC 20 and NBC 20 Groups

Baseline Versus	BC 20				NBC 20			
	Digit	Coding	Arith	FDI	Digit	Coding	Arith	FDI
Data 2	+	*						
Data 3	**			*		*	*	*
Data 4		**	+	*	*	*	*	***

Where $^{*}p \leq 0.05$
$^{**}p \leq 0.01$
$^{***}p \leq 0.001$
$^{+}$= trend where $p \leq 0.051$-0.06

As illustrated in table 7.1c above the improvement in cognitive performance from the baseline measurement was greater for the BC 20 group at data collection 2 when there was a significant increase in the coding score for this group. Whilst there was an improvement for the digit span test at data collection 3 for the BC 20 group ($p \leq 0.01$) and none for this subtest in the NBC 20 group, there were more significant improvements at this data collection period overall for the NBC 20 group. At data collection 4 there were significant improvements only for the coding score and FDI for the BC 20 group, whilst there were improvements for all 4 subtests measured in the NBC 20 group.

7.1.2 Discussion

These findings are similar to the findings of the cross-sectional analysis (C.S) of the data (chapter 4.1). In the C.S part of the study there were also small improvements for the BC group at data collection 2 and not for the NBC group. At data collection 3 there were some improvements in scores for the BC group but more so in the NBC group. By data collection 4 there were more improvements for the NBC group than the BC group. Whilst the magnitude of improvement for the BC group (of the C.S study) from baseline to data collections 3 and 4 was greater than the improvement for the BC 20 group of the L.S analysis the pattern in increase in score was the same.

The BC 20 group reached a plateau in improvement in scores whilst the NBC 20 group continued to increase their improvement in scores as the study progressed. In order to assess the possible influences that the nutrient content of the breakfast meal of these 2 groups may have had on the test scores, it is necessary to look at the differences in breakfast between the BC 20 and NBC 20 groups. Whilst chapter 6.1 has already explored the differences between the breakfast for the 3-days that this meal was assessed, the breakfast on the actual day of cognitive performance testing must be investigated in order to explore tests scores and nutrient intake. This is because cognitive performance in well nourished populations is likely to be affected by the short term intake of food. As outlined in chapter 1 the specific content of food affects certain biochemical and hormonal functions in the body and brain, thus linking diet to behaviour and cognition. In fact rapid and specific changes in brain composition normally occur after each meal (Wurtman *et al.*, 1974).

The next chapter (7.2) describes the differences between the breakfasts of the BC 20 and NBC 20 breakfast on the day of testing and significant changes from the baseline breakfast before the commencement of the breakfast club for each group. In order to differentiate this particular meal from the analysis of the 3-days of breakfast it has been designated the term 'cognitive breakfast'.

7.2 Cognitive Breakfast

The breakfast consumed on the morning of cognitive function testing was referred to as the 'cognitive breakfast'. The BC20 group refers to the breakfast club group who were receiving breakfast at school and the NBC20 group refers to the group who were consuming breakfast at home or on the way to school.

The nutritional results of this breakfast was included in the mean for the calculation of the 3-days of breakfast analysed in chapter 6.1. Access to the breakfast club register and the timetable of test days has enabled the breakfast eaten on the day of psychological testing to be investigated alone. The differences between the breakfast club group (BC) and non-breakfast club group (NBC) has been explored.

The purpose of this chapter is to:

(1) investigate the nutritional differences of the breakfasts consumed by the BC and NBC groups on the morning of cognitive performance testing

Subject Numbers Characteristics

Chapter 7.1 examined the difference between the cognitive performance test scores of the BC and NBC groups. Since this chapter aims to investigate the difference in breakfasts between the 2 groups subjects number and characteristics are the same as the those described in chapter 7.1.

7.2.1 Baseline – October/November 2000

Macronutrient Differences at Baseline Breakfast for the BC20 and NBC20 group

There were no differences between the groups for calories at baseline. The BC20 breakfast provided 221.7±23.1kcal whilst the NBC20 breakfast supplied the children with 243.5k± 26.9kcal. In terms of % RNI for calories the breakfast provided 11.0± 1.3% and 13.7± 1.8% respectively. Percentage energy from carbohydrate was 5.6% higher in the NBC20 group than the BC20 group, whilst percentage energy from fat was 5.3% higher in the BC20 group than he NBC20 group. There were no differences in protein in the 2 groups. The percentage energy from the PUFA, MUFA and SFA was similar in both groups. There was a difference in the amount of starch *per se* between the 2 breakfast groups at baseline. The BC20 breakfast had 15.1±2.2g of carbohydrate whilst the NBC20 breakfast contained 24.1± 3.9g ($p \leq 0.05$). Percentage energy from starch was 8.5% higher in the NBC20 group. Sugar and percentage energy from this source was the same at baseline.

Micronutrient Differences at Baseline Breakfast for the BC20 and NBC20 Group

There were no differences between the groups at baseline for the micronutrient Ca. Breakfast provided 118.3±16.7mg and 140.5±16.6mg for the BC20 and NBC20 group respectively which equated to 21.5±3.0% and 23.2±2.8% of the RNI for Ca. The BC20 group were consuming 22.2±12.1mg of vit C at baseline whereas the NBC20 group were consuming only 1.9±1.1mg at the breakfast meal. This meant that whilst the BC20 group were receiving 73.9% of their vit C intake at breakfast the NBC20 group were obtaining only 10.7±5.7% of this vitamin from the breakfast meal. There were differences in vitamin B_1, nicotinic acid and vitamin B_6 from the breakfast meal at baseline for the 2 groups.

The NBC20 had double the amount of vitamin B_1 at breakfast as compared to the BC20 group, i.e. 0.4±0.08mg versus 0.2 ±0.06mg. As indicated in 7.2b this lead to a difference in the % RNI for these 2 vitamins provided by the breakfast meal with 26.7±6.1% of the RNI for B1 being achieved by the BC20 group and 47.8±6.4% by the NBC20 group ($p \leq 0.05$). The NBC20 group were consuming greater amounts of nicotinic acid at breakfast as compared to the other breakfast group 7.1±1.3mg versus 4.4±0.6mg ($p \leq 0.051$-0.06). This resulted in a difference in the % RNI of nicotinic acid of the 2 groups since the NBC20 breakfast provided 50.6% of the RNI for nicotinic acid and the BC20 breakfast provided only 33.5% of this micronutrient ($p \leq 0.05$). There was double the amount of vitamin B_6 in the NBC20, i.e. 0.6±0.1mg versus 0.3±0.07mg ($p \leq 0.051$-0.06). Vit B_{12}, folate and vitamin D were similar for both groups.

7.2.2 Nutrient Intake at Breakfast on the Day of Cognitive Performance Testing for the BC and NBC groups at data collections 2,3 and 4

At baseline there were no significant differences in the types of breakfast eaten by the BC 20 and NBC 20 group other than that there were no children eating both cereal and toast in the NBC 20 . However after the commencement of the breakfast club there was a significantly higher percentage of cereal eaters ($p \leq 0.05$) in the NBC 20 group as compared to the BC 20 group which had a higher % of cooked breakfast eaters or children eating toast with margarine. The types of breakfast eaten by the BC 20 and NBC 20 groups on the morning of cognitive performance testing are illustrated below (see Fig: 7.2a). This has an impact on the macronutrient and micronutrient composition of the different types of breakfast, which are describes in the tables below.

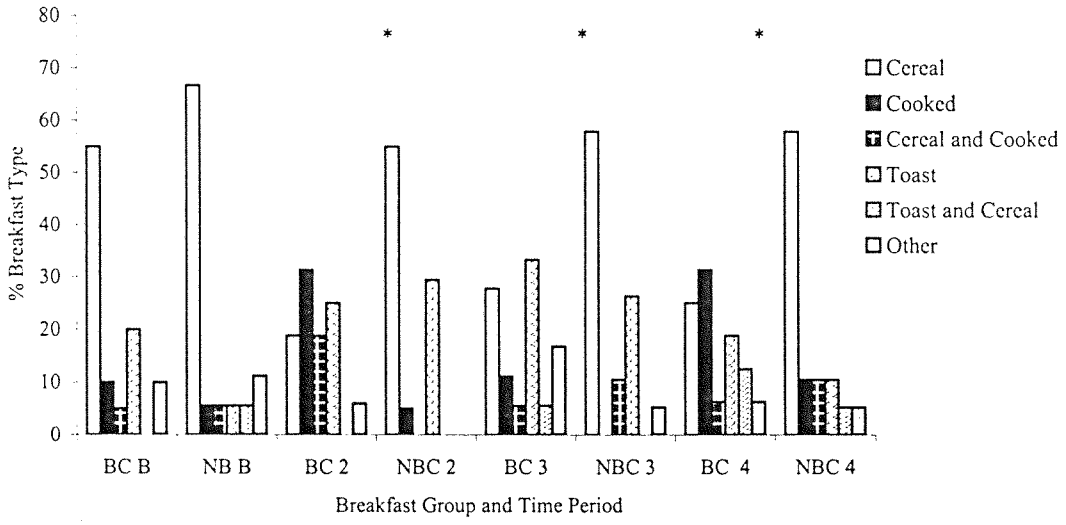


Fig:7.2a Types of breakfasts eaten by the BC 20 and NBC 20 on the morning of cognitive test performance.

where * $p \leq 0.05$ (and number of cereal eaters NBC 20 > BC 20)

Macronutrient Intake at Breakfast on the Day of Cognitive Test Performance

At the baseline measurement the breakfast of the NBC 20 group had non-significantly yet greater amount of CHO(g) and % energy CHO (see figure 7.2b and 7.2c).

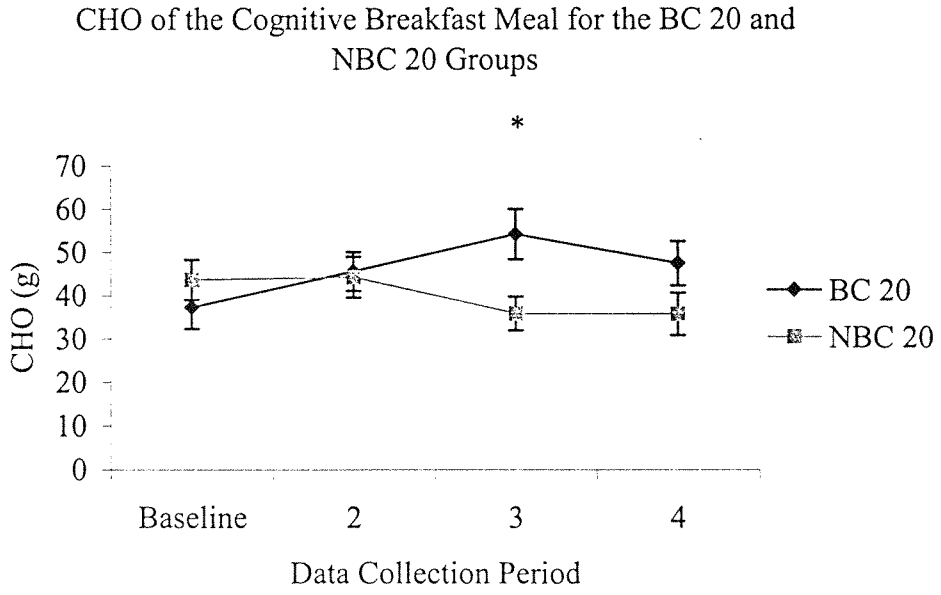


Figure: 7.2b CHO of the Cognitive Breakfast Meal for the BC 20 and NBC 20 Groups
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

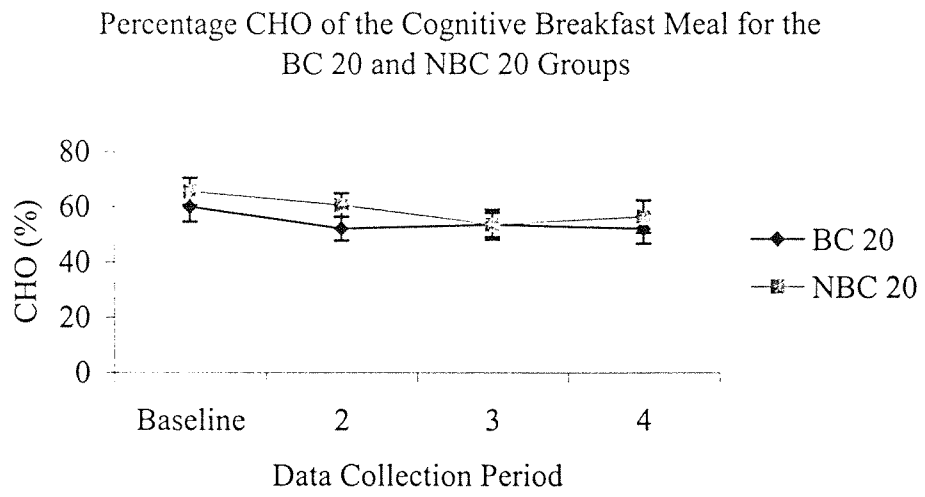


Figure: 7.2c Percentage CHO of the Cognitive Breakfast Meal for the BC 20 and NBC 20 Groups
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

At data collection 2 there was a significantly higher % of energy from starch for the NBC 20 group (see fig 7.2d), but overall the % energy from CHO was higher (but not

significant) in the BC 20 group. The BC 20 group showed an improvement in the coding score as compared to the baseline measurement at this data collection point ($p \leq 0.05$) .

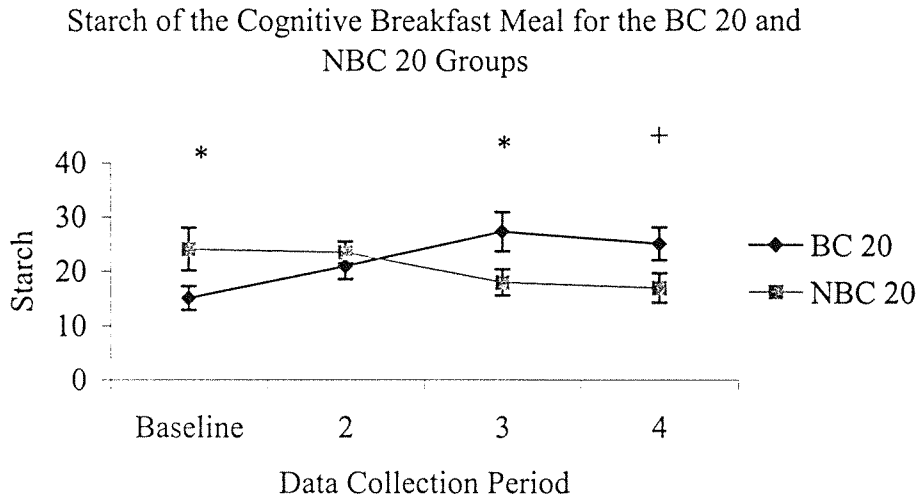


Figure: 7.2d Starch of the Cognitive Breakfast Meal for the BC 20 and NBC 20 Groups
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

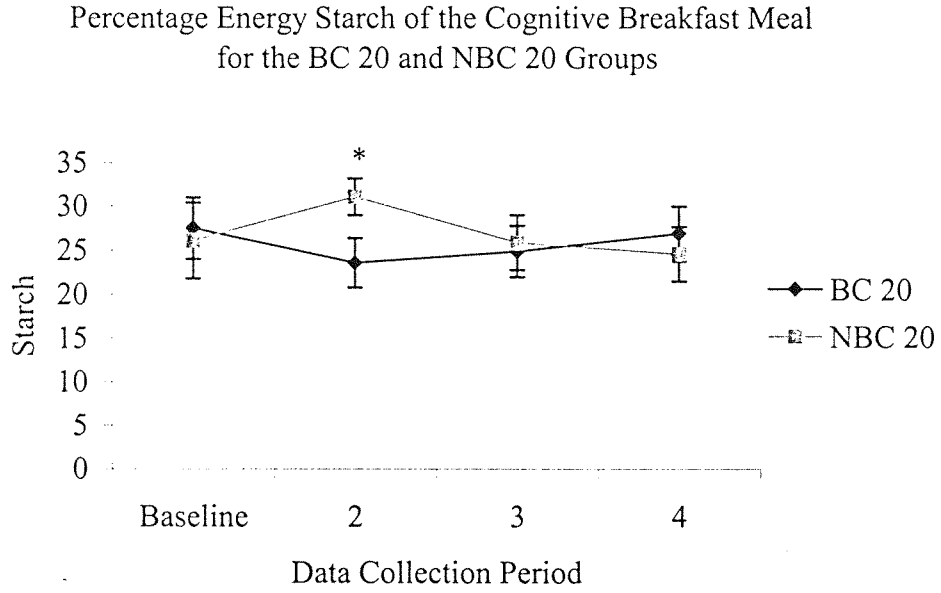


Figure:7.2e Percentage Energy Starch of the Cognitive Breakfast Meal for the BC 20 and NBC 20 Groups
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

At data collection 3 the % energy for CHO was the same in both groups. As illustrated in figures 7.2f-7.2g sugars(g) were higher for the BC 20 group($p \leq 0.05$) but % energy from sugars for the breakfast meal were higher for the NBC 20 group (but not significant).

Sugar of the Cognitive Breakfast Meal for the BC 20 and NBC 20 Groups

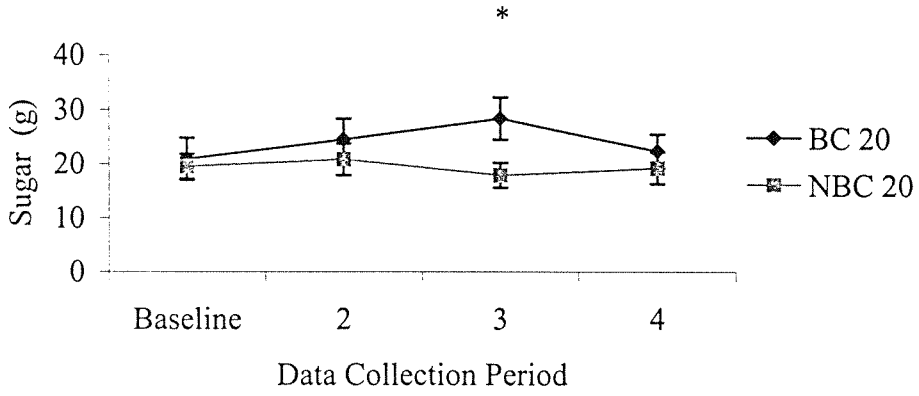


Figure: 7.2f Sugar of the Cognitive Breakfast Meal for the BC 20 and NBC 20 Groups
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

Percentage Energy Sugar of the Cognitive Breakfast Meal for the BC 20 and NBC 20 Groups

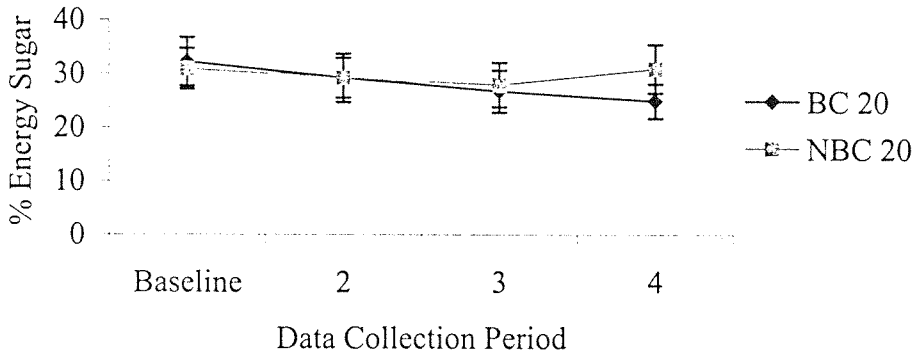


Figure: 7.2g Percentage Energy Sugar of the Cognitive Breakfast Meal for the BC 20 and NBC 20 Groups
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

At the 4th data collection point there was more CHO (g) *per se* in the breakfasts of the BC 20 group but the % of CHO was marginally higher in the NBC 20 group. Whilst the % energy starch was higher in the BC 20 groups breakfast (p= 0.051 – 0.06) the % energy from sugars was higher in the NBC 20 group (see fig: 7.2g).

Fat

As illustrated in fig 7.2h-7.2i below there were differences in the amount of fat in the cognitive breakfast meals of the 2 groups. There was higher % energy from fat, PUFA and MUFA for the BC 20 group at all time periods as shown in7.2j- 7.2m).

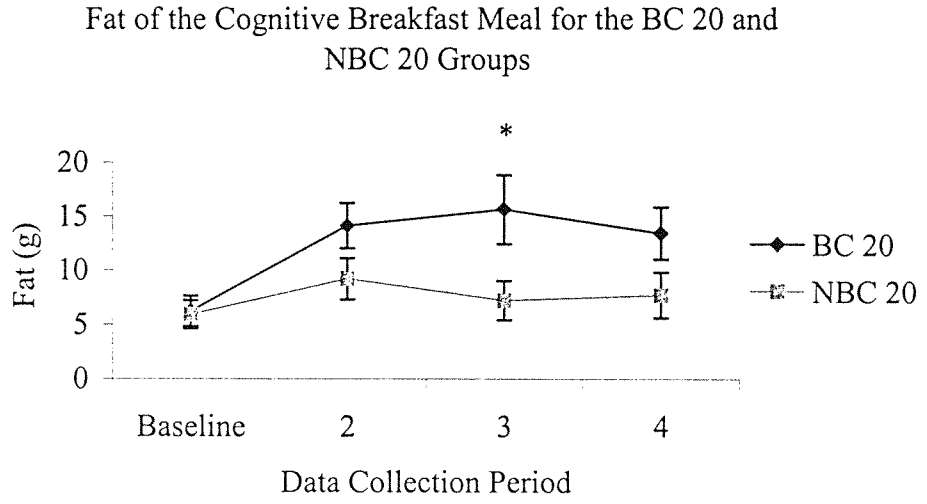


Figure: 7.2h Fat of the Cognitive Breakfast Meal for the BC 20 and NBC 20 Groups
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

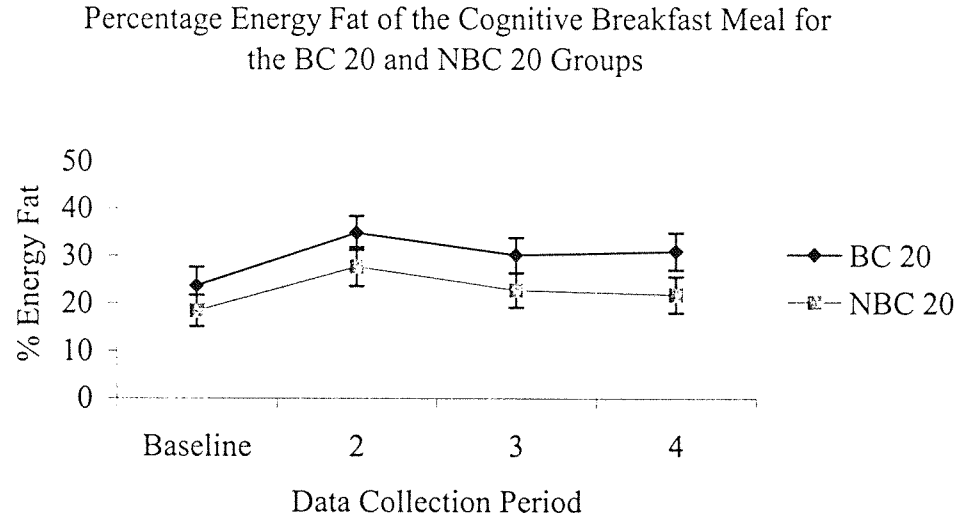


Figure: 7.2i Percentage Energy Fat of the Cognitive Breakfast Meal for the BC 20 and NBC 20 Groups
where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

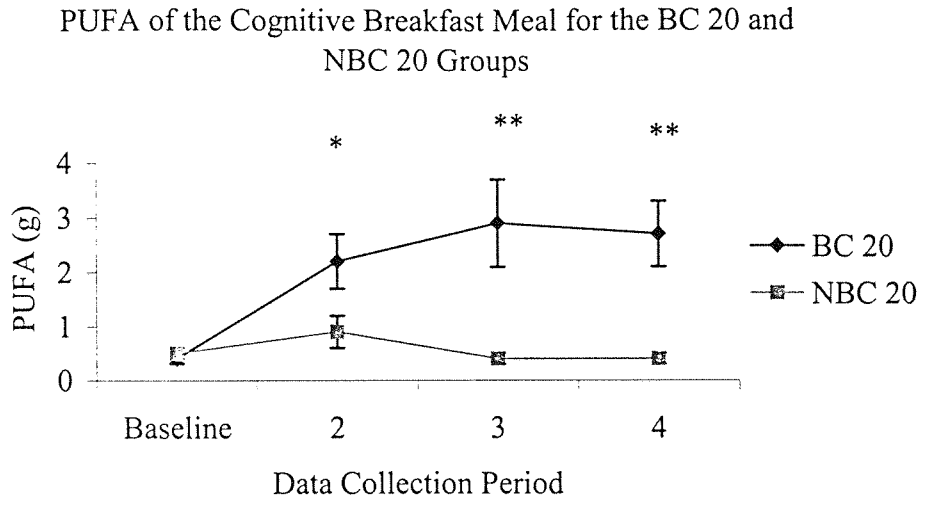
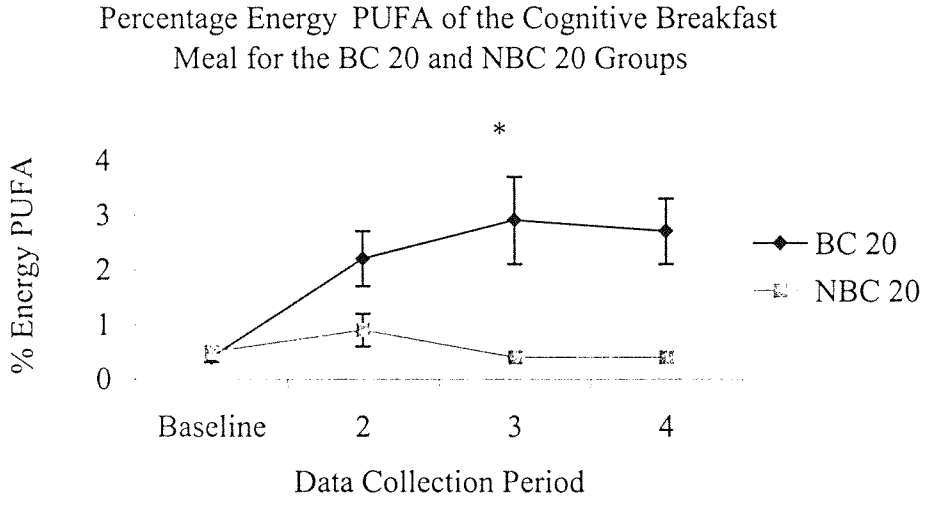


Figure: 7.2j PUFA of the Cognitive Breakfast Meal for the BC 20 and NBC 20 Groups

where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$



where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

Figure: 7.2k Percentage Energy PUFA of the Cognitive Breakfast Meal for the BC 20 and NBC 20 Groups

MUFA of the Cognitive Breakfast Meal for the BC 20 and NBC 20 Groups

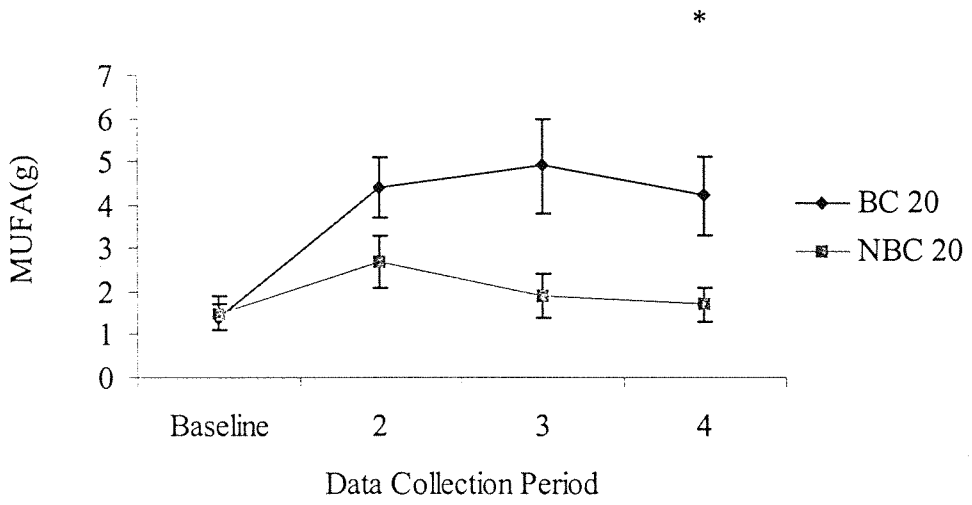


Figure: 7.2l MUFA of the Cognitive Breakfast Meal for the BC 20 and NBC 20 Groups

where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

Percentage Energy MUFA of the Cognitive Breakfast Meal for the BC 20 and NBC 20 Groups

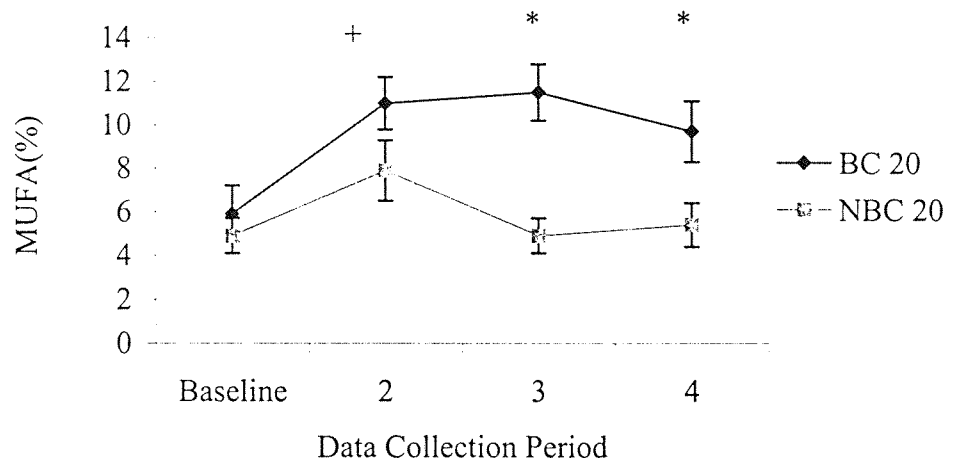


Figure: 7.2m Percentage Energy MUFA of the Cognitive Breakfast Meal for the BC 20 and NBC 20 Groups

where $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

7.2.3 Discussion

At data collection 2,3 and 4 there were significantly greater numbers of cereal eaters in the NBC20 group than the NC20 group ($p \leq 0.05$). As outlined in chapter 1 the specific content of food affects certain biochemical and hormonal functions in the body and brain, thus linking diet to behaviour and cognition. In fact rapid and specific changes in brain composition normally occur after each meal (Wurtman *et al.,* 1974). The mechanisms through which the macronutrients (CHO, protein and fat) can influence the neurochemistry or neural functioning of the brain are beginning to be understood (Dye *et al.,* 2000). Whilst micronutrients (vitamins and minerals) have been shown to both impair and improve some aspects of cognitive performance the effects of these nutrients is implicated over a longer term (i.e. acute effects are unlikely) and is more likely to effect at risk populations, e.g. the elderly and the malnourished.

Unlike other organs, the brain's energy requirements are met almost exclusively through aerobic glucose degradation (except during times of no carbohydrate intake and ketosis). It was traditionally assumed that through a homeostatic mechanism the brain is well supplied with glucose it's primary fuel and that its function is not affected by normal fluctuations and variations in blood glucose (Booth 1994). Recent evidence suggests however that raising blood glucose concentrations improves cognitive functioning (Hall *et al* 1989., Benton and Owens 1993, Owens *et al.,* 1994, Gold *et al.,* 1986, Messier 1987, Green *et al.*,1997).

The differences in the nutritional profile of the breakfasts of the 2 breakfast groups at baseline and after the commencement of the breakfast club are presented in this summary and discussion. The difference in cognitive performance scores from baseline to data collections 2, 3 and 4 (see previous chapter 6.1) have also been discussed with reference to the differences in nutritional intake at the breakfast meal. Bearing in mind that this was a well nourished population where micronutrients are unlikely to have an effect on

cognitive performance, the discussion has focused the effect of macronutrient composition (namely CHO and fat). The next chapter 7.5 will seek out correlations and possible relationships between the cognitive performance scores and nutrients in order to ascertain if any of the hypothesized put forward have any founding.

Since there was a significant difference in the % of children eating cereal breakfasts after the commencement of the breakfast club, there is a difference in % energy from CHO and fat between the groups.

Carbohydrate

At the baseline measurement the breakfast of the NBC 20 group had non-significantly yet greater amount of CHO(g) and % energy CHO .There was no significant difference in cognitive performance between the groups although scores in the NBC 20 group were higher.

At data collection 2 there was a significantly higher % of energy from starch for the NBC 20 group, but overall the % energy from CHO was higher (but not significant) in the BC 20 group. The BC 20 group showed an improvement in the coding score as compared to the baseline measurement at this data collection point ($p \leq 0.05$) .

At data collection 3 the % energy for CHO was the same in both groups. As illustrated in figures 7.2e-7.2f below sugars(g) were higher for the BC 20 group($p \leq 0.05$) but % energy from sugars for the breakfast meal were higher for the NBC 20 group (but not significant). The digit span test had improved for the BC 20 group as compared to baseline ($p \leq 0.01$). Whilst there was an improvement in FDI score for both groups at this time period ($p \leq 0.05$), there was an improvement for the NBC 20 group for the coding and arithmetic test also.

At the 4th data collection point there was more CHO (g) *per se* in the breakfasts of the BC 20 group but the % of CHO was marginally higher in the NBC 20 group. Whilst the % energy starch was higher in the BC 20 groups breakfast ($p= 0.051 - 0.06$) the % energy

from sugars was higher in the NBC 20 group. At this data collection point there were improvements for the coding test and FDI for the BC 20 group but improvements for all of the digit, coding, arithmetic and FDI scores for the NBC 20 group as compared to the baseline measurement.

From these results we can postulate that cognitive performance may be affected by % energy of total CHO, starch and sugars. Glucose is the main source of the acetyl groups used in the formation of acetyl CoA) (Tucek, 1983) by oxidation of pyruvate dehydrogenase (Cooper *et al.,* 1986) and the association between acetylcholine-mediated neurotransmission and memory is well accepted (Bartus *et al.,* 1982, Durkin *et al.*,1992, Kopelman, 1986). In additon to its role in cholinergic biochemistry glucose also contributes to the production of energy for brain neurons (e.g. ATP) (Tyce *et al.,* 1983). Carbohydrate provides the most rapidly available source of glucose the brain's primary metabolic fuel (Dye *et al.,* 2000). A breakfast higher in percentage energy from CHO might benefit short-term memory by supplying the brain with a readily available and steady supply of this fuel. Therefore the % of energy of CHO, starch or sugars of the breakfast meal may influence the supply of glucose and hence acetylcholine and ATP to the brain, thereby affecting performance. There is a wealth of evidence documenting the beneficial effects of a glucose drink on cognitive performance in healthy young adults (e.g. Benton *et al.,* 1987, 1989, 1990, 1995, 1999 Conners *et al.,* 1984, Foster *et al.,* 1998) . Research into breakfast at school and cognition have mainly focused the non-breakfasted versus breakfasted condition in undernourished or malnourished children where a positive impact from eating breakfast would be expected. There are relatively few studies that have looked at different breakfast types and cognitive performance specifically. Smith looked at the effect of a cooked breakfast versus cereal and toast in a group of students (Smith *et al.* 1994). Whilst breakfast had no effect on the performance of sustained attention tasks, there was an improvement in mood for students eating a cooked breakfast. In contrast Lloyd showed that significant improvements were found in his group of

students when they consumed a low fat, high-CHO breakfast as opposed to a high fat-low CHO meal (Lloyd *et al.,* 1996). The specific effects of a cereal breakfast on child performance have been researched recently and have shown that declines in attention and memory are significantly reduced by the consumption of cereal in the morning as compared to the no breakfast condition or a glucose drink (Wesnes *et al.,* 2003). The researchers concluded that a cereal breakfast had a positive effect on the cognitive function of schoolchildren, particularly towards the end of the morning and that a typical breakfast of cereal rich in complex CHO can help maintain mental performance over the morning. Benton *et al.,* 2003 found that a breakfast high in slowly rather than rapidly available glucose benefited memory later in the morning. Whilst it has been beyond the parameters of the thesis to look at glycaemic index (GI) or glycaemic load (GL) this is a factor that should also be taking into consideration when interpreting the results.

Fat

There were differences in the amount of fat in the cognitive breakfast meals of the 2 groups. There was higher % energy from fat, PUFA and MUFA for the BC 20 group at all time periods. This was due to the higher % of cooked breakfast and toast with margarine being consumed by the BC 20 group. Little decisive research has been carried out regarding the effect of diet fat on performance On balance, high-fat meals appear to increase subsequent fatigue and reduced reported alertness, but with little effect on cognitive performance, relative to high-CHO-low-fat meals. Wells and Read (1996) found that subjects felt less vigorous and more dreamy and feeble after a low CHO/high fat meal. It was suggested that the mood changed reflected the fat rather than the CHO since lipid infusion into the duodenum was found to reduce alertness (Wells *et al.,* 1995). In contrast Holt (1999) found that participants who consumed a high fibre cereal, were more alert than after the consumption of a fat-rich meal. The effect of fat on fatigue would not be a consideration in the present research since cognitive testing took place 30mins-1.5 hrs after breakfast at which point duodenal fat would not be able to produce a change in systemic

nutritional state. Nevertheless the changes in fat and % energy fat will affect the % energy of CHO, since intakes % there were no differences in % energy protein from the breakfasts of both groups and % energy from protein remained relatively stable throughout the study.

7.3 Nutrient and Cognitive Performance Correlations

The relationship between nutrient intake at breakfast and the digit span, coding and arithmetic subsets of the WISC-III^{uk} were explored. Nutrient composition of the breakfast consumed on the day of administration of the cognitive tests (i.e. the 'cognitive breakfast' was correlated to cognitive performance scores using Pearson Correlations.

The purpose of this chapter is to investigate the acute effects of breakfast on cognition. Hence relationships between carbohydrate (including total sugars and glucose, sucrose, maltose, lactose and fructose separately), protein and fat and percentage energy of these nutrients have been presented below. Correlations between some micronutrients and cognitive function are also shown in this chapter.

In the tables below total population refers to both the BC 20 (breakfast club 20) group and the NBC 20 (non breakfast club 20) group. Correlations between nutrients and cognitive scores were explored for the total population and the BC 20 and NBC 20 group separately.

7.3.1 Positive Correlations Between Nutrients Eaten at Breakfast and Cognitive Performance Scores

Tables 7.3a and 7.3b below illustrate the positive correlations between nutrients at breakfast and cognitive performance for the total population. At data collection 4 there was an association between % energy from fat, PUFA and SFA and the digit and arithmetic subset.

Table: 7.3a Macronutrient and Cognitive Performance Correlations For the Total Population

Nutrient	Digit	Coding	Arithmetic
% Energy Fat	Data 4		
% Energy PUFA			Data 4
% Energy SFA(g)	Data 4		
% RNI CHO		Baseline	

The possible relationship between micronutrient intake and cognitive performance has not discussed so far because micronutrient intakes are only likely to affect malnourished and undernourished populations over a period of time. The children in this study were well nourished. Correlations between micronutrients and cognitive performance measures however have been summarised below (figure 7.3b).

Tables: 7.3b Micronutrient and Cognitive Performance Correlations for the Total Population

Nutrient	Digit	Coding	Arithmetic
Calcium (mg)		Data 2	
% RNI Calcium		Data 2	
Vitamin C (mg)	Baseline		
% RNI Vitamin A	Data 4		Data 4
% RNI Vitamin B1	Data 4		
Vitamin B2 (mg)		Data 4	
% RNI Vitamin B2		Data 4	
% RNI Nicotinic Acid		Data 4	
Vitamin B6 (mg)		Data 3	
% RNI Vitamin B6		Baseline, Data 4	Data 4
Folate (ug)		Data 3, 4	
% RNI Folate		Data 3, 4	
Vitamin D (ug)		Data 3	Data 2

There was a positive association for carbohydrate and % energy from starch for the arithmetic scores and digit span test for the BC group (see table 7.3c).

Tables: 7.3c Macronutrient and Cognitive Performance Correlations for the BC Group

Nutrient	Digit	Coding	Arithmetic
CHO(g)	Baseline		Data 4
% Energy Starch	Baseline		Data 3

There were also correlations between micronutrients and performance for the BC group as illustrated in table 7.3d.

Tables: 7.3d Micronutrient and Cognitive Performance Correlations for the BC Group

Nutrient	Digit	Coding	Arithmetic
Calcium (mg)		Data 2	
% RNI Vitamin A		Data 2	
Vitamin B_1 (mg)	Baseline		
% RNI Vitamin B_1	Baseline		
% RNI Vitamin B_2		Data 2	
Nicotinic Acid (mg)	Baseline		
Vitamin B_6 (mg)	Baseline		
Folate (ug)	Baseline		
% RNI Folate	Baseline		

There were correlations for the digit span test and fat for the NBC group (see table 7.3e). Coding was positively correlated to carbohydrate for the NBC group . At data collection 3 and 4 the arithmetic test were also positively associated with CHO for this group.

Table: 7.3e Macronutrient and Cognitive Performance Correlations for the NBC Group

Nutrient	Digit	Coding	Arithmetic
Calories (Kcal)			Data 3
% Energy Fat	Data 2, 3		
% Energy CHO		Baseline	
Fat (g)	Data 3		
PUFA (g)	Data 3		Data 3
% Energy PUFA			Data 3
MUFA (g)	Data 3		Data 3
% Energy MUFA	Data 2		
SFA (g)	Data 3		Data 3
% Energy SFA(g)	Data 2, 3	Baseline	
CHO(g)		Baseline	Data 3, 4
% RNI CHO		Baseline	

The coding score was associated to the B-vitamins at data collection 4 for the NBC group (table 7.3f) mainly at data collection 4.

Figure: 7.3f Micronutrient and Cognitive Performance Correlations for the NBC Group

Nutrient	Digit	Coding	Arithmetic
% RNI Fe		Data 4	
% RNI Vitamin A	Data 3		
Vitamin B_1 (mg)			
% RNI Vitamin B_1		Baseline and Data 4	
Vitamin B_2 (mg)		Data 4	
% RNI Vitamin B_2		Data 4	
Nicotinic Acid (mg)		Data 4	
% RNI Nicotinic Acid		Data 4	
% RNI Vitamin B_6		Data 4	
Vitamin B_{12} (ug)		Data 4	
% RNI Vitamin B_{12}		Data 4	
Folate (ug)		Data 4	
% RNI Folate		Data 4	
Vitamin D (ug)		Data 4	

7.3.2 Discussion

Whilst there were correlations for fat and cognitive test performance the mechanisms behind this are unclear. Lloyd *et al.,* (1996) looked at the differences in cognitive performance after a low-fat, high-CHO breakfast, a medium-fat, medium-CHO breakfast and a high fat, low-CHO breakfast. Whilst he found no difference in free recall, simple and reaction time, he found that there was an improvement in mood for the low fat, high-CHO breakfast group. Smith who looked at differences between the no breakfast and a cooked breakfast found that the cooked breakfast had no effect on sustained attention but affected free recall in the mid-morning (Smith, 1992). The mechanisms behind which fat may affect cognitive performance have been discussed in the discussion in chapter 7.2. On balance it appears that high-fat meal are likely to increase subsequent fatigue and reduce reported alertness, but with little effect on cognitive performance relative to high-CHO-low-fat meals (Dye *et al.*, 2002). Whilst fat may affect alertness this would not be a consideration in this study since lipids from a meal is not likely to reach the duodenum in

substantial amounts until 2-3hrs after ingestion (Wells *et al.,* 1995). The children in the present study were tested 30- 1.5 hours after eating breakfast.

Coding was positively correlated to carbohydrate and overall it appears that the coding score especially is sensitive to CHO levels for the NBC group. Coding is a test of attention which may be susceptible to blood glucose levels. The arithmetic test were also positively associated with CHO for the NBC group. The NBC group were high cereal consumers. There was a positive association for carbohydrate and % energy from starch for the arithmetic scores and digit span test for the BC group also. Most studies which have looked at relationships between food and cognitive performance have looked at correlations between blood glucose levels. One of the limitations of the present research was that it was not possible to take blood samples from the children for biochemical analysis. There has been a plethora of research to show the improvement of cognitive performance after administration of glucose (Benton *et al.,* 1987, 1989, 1990, 1995, 1999, Conners *et al.,* 1984, Foster *et al.,* 1998) and recent evidence by Wesnes revealed that blood glucose levels following cereal consumption lead to improved memory as compared to other types of breakfast (Wednes, 2003). Since CHO foods are readily digested and metabolised to produce glucose the brain's preferred metabolic fuel, this could provide an explanation for the positive association shown in table 7.3n below. The mechanisms behind which glucose effects cognitive function has been covered in section and will be further discussed in the final discussion.

The possible relationship between micronutrient intake and cognitive performance has not discussed so far because micronutrient intakes are only likely to affect malnourished and undernourished populations over a period of time. The children in this study were well nourished.

There were correlation between the B-vitamins and test performance but this may especially for the NBC group. This may however reflect the fact that there were high

numbers of fortified breakfast cereal eaters (high in CHO) in this group rather than the effects of the B-vitamins *per se*. It is a common finding that psychological function decreases with age, and there is a large body of evidence however which indicates that vitamin status is an important mediator in the maintenance of efficient cognitive processing (Dye *et al.,* 2002. In particular a number of vitamins have functional utility in the maintenance of the central and peripheral nervous system. Deficiencies in the B-vitamin group (thiamin, B_2, B6, B12 and folate) have been linked with conditions such as irritability, depression, peripheral neuropathy and myelin degeneration. (Rosenberg and Miller, 1992). One possible route whereby deficiencies in these vitamins may affect cognition relates to their role in the metabolism of the S amino acid homocysteine. Plasma levels of homocysteine have been inversely correlated to levels of B12 (Koehler *et al.,* 1996; Lussier-Cacan *et al.,* 1996), vitamin B6 and folate (Selhub *et al.,* 1993). Importantly, supplementation with a range of B-complex vitamins reduces serum homocysteine levels in both the elderly (Koehler *et al.,* 1996) and younger (Woodside *et al.,* 1998) populations. It has been found that Alzhiemer's patients exhibit significantly higher levels of homocysteine (McCaddon *et al.,* 1998) and these levels are also predicative of neuropsychological status in individuals suffering from other forms of dementia (Lehman *et al.*, 1999). A recent study by Bryan *et al.* (2002) revealed that supplementation of the B-vitamins in a group of 211 health middle aged women had a positive effect on memory performance. Dietary intake status was associated with speed of processing, recall, recognition and verbal ability. As yet there have no such studies in children but the positive correlations between cognitive performance in the B-vitamins shown in Figure 7.3b below require further investigation.

8.1 Child Behaviour

Child behaviour was measured using the Achenbach Teacher Report Form (see chapter 2.10). The report form was completed by the form teacher at baseline and at data collection 4. As described in the methodology the report form was shortened for this study due to time restraints. The results however can still be divided into the original domains for scoring.

8.1.2 Baseline – October/November 2000

At the baseline measurement the breakfast clubs had not commenced in the breakfast club schools. At data collection 2, 3 and 4 children who attended the breakfast club were classed as the BC 20 group and those who did not attend the breakfast club group were the NBC 20 group.

Child Behaviour at Baseline of the Breakfast Club Group BC 20 and Non Breakfast Club NBC 20 Group.

The following domains were measured by the Achenbach teacher report form :

academic performance, working hard, behaving appropriately, learning,happiness

adaptive functioning, withdrawn behaviour, somatic complaints, somatic score, anxiousness/depression, internalising behaviour, social problems, thought problems, attention problems, inattention, hyperactivity-inpulsitivity, delinquent behaviour, aggressive behaviour, externalising behaviour and other problems..

Referring to figure 8.b below there were differences in diligence between the 2 groups. The BC 20 group (n=20) were working harder than the NBC 20 group (n=16) (p=0.04). Figure 8.1b also represents a difference between the groups. The NBC 20 group were suffering from inattention to a greater extent than the BC 20 group (p=0.02).

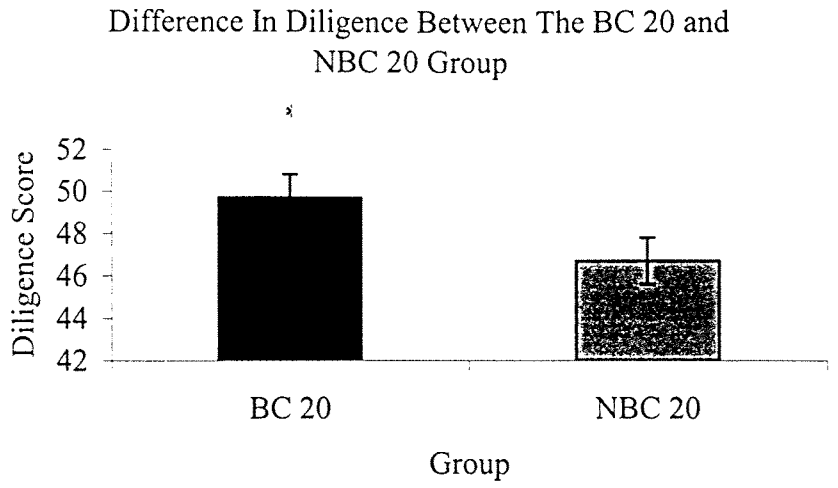


Figure: 8.1a Difference In Diligence Between The BC 20 and NBC 20 Group where * $p \leq 0.05$

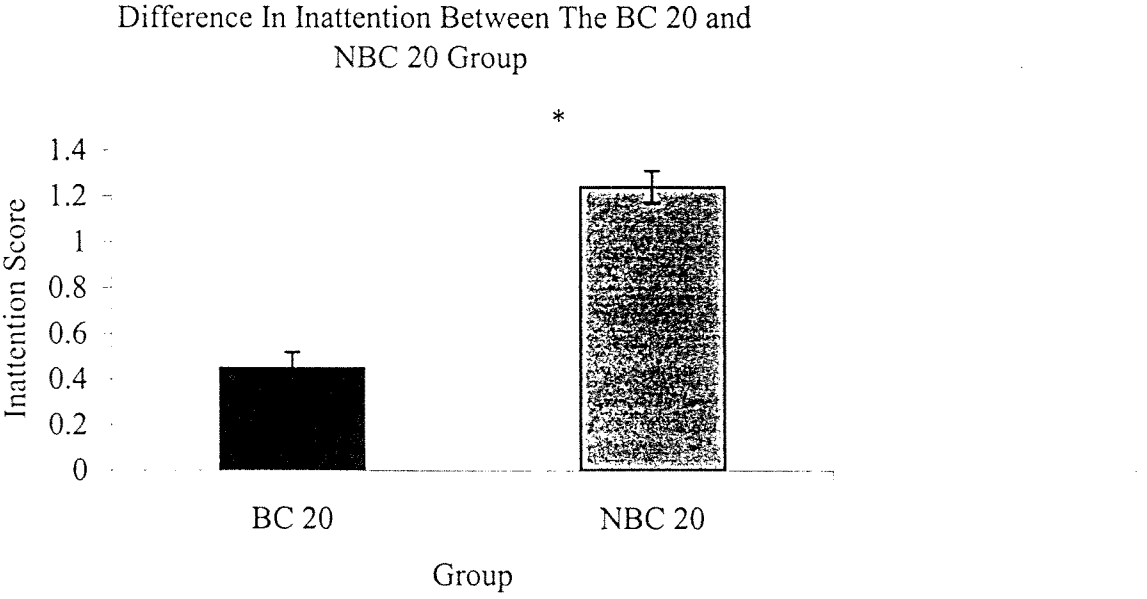


Figure: 8.1b Difference In Inattention Between The BC 20 and NBC 20 Group

where * $p \leq 0.05$

8.1.2 Data Collection 4 – May- June 2001

At data collection 4 Teacher Report Forms were unmarked by one of the breakfast club schools. Therefore it has not been possible to analyse the data for this data collection period.

9.1 Anthropometry

At baseline and the 3 subsequent data collection periods anthropometric measurements were taken in all four schools (as described in chapter 2.9). In this chapter the height, weight, BMI , fat free mass (FFM), fat mass (FM), % body fat and growth velocity is explored for the BC 20 and NBC 20 groups. At baseline all children were consuming breakfast at home. At data collection 2,3 and 4 the BC 20 children were eating breakfast at school and at these 3 data collection points the NBC 20 children were eating breakfast at school.

The purpose of this chapter therefore is to examine the differences in height, weight, BMI FFM, FM, % body fat and growth velocity of the BC 20 and NBC 20 groups at baseline and data collection 2, 3 and 4

The following measurements were made and are described below.

1) Body Mass Index (BMI)

$$\frac{\text{Weight (kgs)}}{\text{Height x Height (m}^2\text{)}}$$

2) Biolelectrical Impedence Measurements

Fat free mass (FFM), (fat mass) FM and % body fat calculated according to the equation of Deurenberg (1990).

$$FFM = 0.406 \times 10^4 \times H^2/R = 0/360\ W + 5.58\ H + 0.56\ Sex - 6.48$$

Where

W = body weight in kg

H = body height in metres

Sex (male = 1, female = 0)

3) Growth – height velocity and weight velocity

Growth velocity was expressed in terms of centimetres gained per year for height (height velocity) and kilograms per year for weight (weight velocity).

Calculation for velocity:

$$\text{Growth velocity} = \frac{\text{Measurement at data collection 2 , 3 or 4 – Baseline Measurement}}{\text{Number of days between measurements}} \times 365$$

Parametric and Non-Parametric Data

Tests of normality were carried out on the anthropometric variables and the expected skewness observed by Cole (1990) was present for weight and BMI in some of the groups and for certain data collection points. Parametric and non-parametric tests to explore the differences between the groups were carried out accordingly. The non-parametric data have not been presented however in terms of the median and interquartile range, but has been represented as means and Seems. All data represented therefore as means. This is because there were no statistical differences between the groups for any of the measurements and so for consistency all the results below have been described in the same way.

The Change in Anthropmetric Measurements From Baseline

The change in body measurements from baseline from data collection 2 ,3 and 4 have been presented below. These are shown in the table below by the body measurement description followed and data collection period by the term - (minus) baseline.

9.1.1 Baseline- October/November 2001

Table 9.1a : Group Descriptive for Anthropometric Measurements at Baseline

	Breakfast Club 20	Non- Breakfast Club 20
No. of Subjects	20	20
Gender	10F:10M	10F:10M
Age of Subjects	9.2(±0.3)	9.1(±0.3)

The groups were matched for gender, age, height, weight and BMI at baseline and these measurements are shown in table 9.2 below. There were also no differences in FFM, FM and % body fat at baseline.

Table: 9.1b Anthropometric Measurements At Baseline

	Breakfast Club	Non-Breakfast Club
Height (cm)	136.1 (±1.5)	135.1 (± 1.8)
Weight (kg)	32.1 (±1.4)	30.6 (± 1.2)
BMI (kg/m^2)	17.6 (±0.8)	18.5 (± 0.6)
Fat Free Mass (kg)	23.6 (± 0.9)	22.8 (± 0.9)
Fat Mass(kg)	8.4 (± 0.7)	7.9 (± 0.4)
% Body Fat	25.9 (± 1.1)	25.7 (± 0.9)

9.1.2 Anthropometric Measurements at Data Collections 2,3 and 4 and Height and Weight Velocity

There were no differences between the BC20 and NBC20 for any of the body measurements including height and weight velocity at data collections 2,3 and 4.

9.1.3 Discussion

Mean height over the course of the study for the BC 20 group was 137.9cm whereas mean height for the NBC 20 group was 137.3cm. The mean height for Scottish 9 year olds in the longitudinal study by Hughes et al (1997), that monitored the growth of 2000-3500 Scottish children from 1972 to 1994 was 135.8cm in 1994. Whilst the children in the present study are marginally taller there was no statistical difference between them and the children in Hughes study. Mean height for this age group in 1972 was 132.7cm (Hughes et al 1997) and so the results of the present study confirm the findings that in developed countries children are getting taller with each generation (Tremblay and Williams, 2000 and Freedman *et al,* 2000).

The average weight for 9 year olds in the Scottish sample of the 1997 longitudinal was 30.9kg, whilst the BC 20 group in this study had an average weight of 33.9kg and the NBC group showed a mean weight of 32.5kg. The average weight of 9 year old children in the 1972 study was 28.1kg. This reveals the trend of increasing weight in children in developed countries. Increases in height will naturally lead to increases in weight, but this is a

worrying trend if weight gain is also due to excess body fat as well as skeletal and tissue growth. The prevalence of obesity in primary school aged children has increased reaching 1.7% (English boys) 2.1% (Scottish boys), 2.6% (English girls), and 3.2% (Scottish girls) (Chinn and Rona, 2001). In Chinn and Rona'a study the Scottish school children were significantly shorter than there English counterparts Also measurement of body fat showed that there was an increase in both groups but fatness was slightly higher in the Scottish group. The authors suggested that this indicated a trend towards obesity in Scottish school children particularly.

FFM was calculated using the equation of Deurenberg which is age and sex specific (Deurenberg *et al.,* 1991). There were 62 children in the age 7-10 group in the Deurenberg study and FFM was 23.7 (± 3.7)kg. At baseline FFM for the BC20 group was 23.6± 0.6kg and 22.8 ± 0.9kg for the NBC20 group. Mean FFM for the BC20 group after the start of the breakfast club was 24.1kg whilst it was 23.1kg for the NBC group. These findings are in-line with the findings of Deurenberg. In the Deurenberg *et al.* (1989) study of pre-pubescent children he found FFM to be 24.1kg for 8-11 year old children and that % body fat was 21.6kg. Percentage body fat for the BC 20 in the present study was 25.9%, and was 26% NBC 20. This indicates that whilst FFM is in-line with other studies on children the % of body fat in this group of children is higher. Whilst none of the children in the longitudinal study were overweight these increases in % body fat is a worrying trend. Childhood obesity is one of the major public health issues of today and its causes are no doubt multi-factorial. However it is a certainty that diet and exercise play an intrinsic part in maintaining a healthy weight and body composition. If breakfast clubs are to provide children with a beneficial start to the day, it should take into consideration the nutritional profile of the breakfast to ensure that it contributes the correct type of nutrients to keep children healthy.

Whilst there were some differences in the daily intake of nutrients between the BC 20 groups and in the breakfast composition of these 2 groups this had no effect on the growth and body composition of these 2 groups. Overall the BC 20 group had a higher daily fat intake than the NBC 20 group whilst the breakfasts of the BC 20 group were in general higher in calories, fat , protein, calcium, vitamin C and A. Only a few studies have shown an improvement in children's nutritional status by way of a increase in growth velocity with school feeding and these are in developing countries where improved nutrient status has had a positive effect on growth in undernourished children (Grantham-McGregor *et al.,* 1998, Paige *et al.,* 1976, Argarwal *et al.,* 1987, Lancet *et al.,* 1928, Leighton *et al.,* 1929, Lininger *et al.,* 1933). There has been no such evidence in well nourished populations. This is because they are rarely deficient of the nutrients necessary for growth. The next chapter will however look at the relationship between nutrient intake and growth.

9.2 The Relationship Between Dietary Intake and Anthropometric Measurements

Dietary intake at baseline and data collection 2,3 and 4 were assessed using a 3-day food diary (as discussed in the methodology chapter 2.3.) The differences between the BC 20 and NBC 20 groups daily nutritional intake have been discussed in chapter 6.2. Anthropometric measurements were also taken at baseline and data collection 2, 3 and 4. The relationship between body measurements and dietary intake has been explored in this chapter. Linear regression has been used to investigate which nutrients have had an effect on weight, height, weight and height velocity and BMI. In this chapter the relationship between dietary intake and anthropometric measurements have been presented for the entire population of children (i.e. the BC 20 and NBC 20 group together) and for the BC 20 and NBC 20 group separately at baseline, data collection 2 ,3 and 4.

This chapter will attempt to answer the following questions:

1) Is there a relationship between height or weight and energy and nutrient intake?

2) Which nutrients are associated with height and weight, height and weight velocity and BMI?

9.2.1 The Relationship Between Macronutrients and Body Measurements

Significant regression analysis between nutrients and body measurements or growth is illustrated in table 9.2a below. This represents that there is an association between the 2 variables.

Table: 9.2a Summary Table of Body Measurements and Significant Regression Analysis

	Total Population	BC 20	NBC 20
Data 2	Nicotinic acid and height velocity(p=0.01). Vit B_6 and height velocity (p=0.01). Vit C and weight (0.003).		
Data 3	Fat and weight velocity (p=0.03) Ca, Nicotinic acid, Vit D and height. (p=0.05) Vit B_2, B_6 and weight (p=0.01). Vit A and height velocity (p=0.04).	CHO and weight velocity (p=0.04) Ca, Vit C, Vit B_2, Nic, Vit B_6, Vit D and height (p=0.04)	Calories and weight velocity (p=0.02). Nic acid, Vit B_6, folate and height velocity (p=0.03)
Data 4	Calcium and height (p=0.04)		

Correlations such as that shown in figure 9.2a below can be used to predict the nature if the relationship between these 2 variables.

When weight velocity was explored regression analysis showed that fat (g) intake may predict increase in weight. There was also a significant positive correlation between these variables i.e. as fat intake increased so did weight velocity. This correlation is presented in figure 9.2a below.

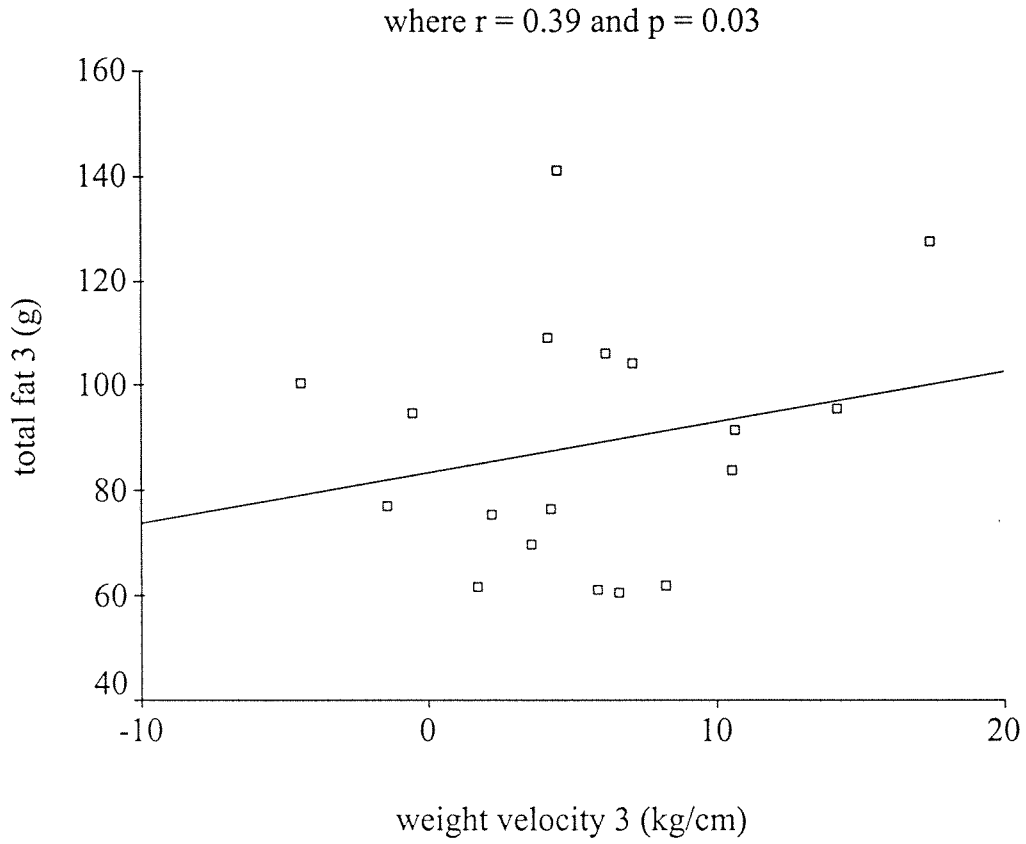


Figure: 9.2a The Association between Body Measurements and Macronutrient Intake for the BC 20 Group at Data Collection 3.

9.2.2 Discussion

Fat intake could be used to predict weight at data collection 3. As fat provides more calories per gram than other constituents do, its addition to a food or diet necessarily increases the energy density. The finding that fat intake can be used to predict weight is expected. In the typical high-fat western diet, most of the triglyceride store is derived from dietary fat (Garrow and James , 9th Edition). CHO intake could also be used to predict weight velocity for the BC 20 group at data collection 3. CHO is a necessary part of the diet and is an important provider of energy (ATP) and is important to avoid ketosis. The

1997 WHO report on carbohydrate and health reported that there is no link between obesity and carbohydrate intake (WHO, 1997). In fact the conversion of glucose and CHO into triglyceride stores is dependent on the pentose phosphate pathway and the pyruvate/malate cycle as suppliers of the $NADPH_2$ required for fat synthesis de novo (Newsholme and Leech 1983; Smith *et al.,* 1983). When the conversion does occur the most important tissue seems to be the liver, although some conversion can occur in adipose tissue and is stimulated by insulin (Sims and Danforth 1987). Calories at data collection 3 could also predict weight velocity in NBC 20, which is expected since calories are the currency of energy. Since the subjects in this research are growing children fat, carbohydrate and calories will also be used as energy and the building blocks for growth of organs, tissues and bones .Whilst there is no association between fat, CHO and height velocity we can still assume that the relationship between these factors and weight and weight velocity reflects growth of organs and tissues.

At data collection 2 nicotinic acid could be used to predict height velocity. Nicotinic acid is important for intermediary metabolism, and the requirement is related to energy expenditure. Vit B_6 could also be used to predict height velocity. This vitamin is of central importance in the body's overall protein metabolism, and hence requirements are related to the total amount of amino acids to be metabolised. Amino acids are important building blocks for tissues. Thus the possible association between these two micronutrients and height velocity is explainable. Vit C and weight also showed an association for the total population at data collection 2. The essential and undisputed riles of vit C in man are to prevent scurvy and to aid wound healing. It also assists in the absorption of non-haem iron, and because of its potential for reaction with destructive free radical containing oxygen , it is an important antioxidant. It could be related to weight therefore in growing healthy children.

At data collection 3, the combination of Ca, nicotinic acid and vit D could be used to predict and height. Of the approximately 1.2 kg (300 mmol) Ca in the human body, about 99% is in the bones and teeth where its primary role is structural. Ca needs in children are high because of skeletal growth. The functionality of nicotinic acid has already been described. Vit D is involved in Ca homeostasis and so is also important for bone health and growth. Therefore the fact that it is possible to predict height from Ca, Vit D and nicotinic acid for the total population at data collection 3 is explainable.

The combination vit B_2, B_6 and A as independent variables could also be used to predict height velocity for the total population of children. Vit B_6 as described before is important for protein metabolism vit B_2 plays an essential role in all the in all the oxidative processes on which man and other organisms depend. Vit A is required for growth and for the normal development and differentiation of tissues.

The independent variables Ca, vit C, vit B_2, nicotinic acid, vit B_6, vit D could predict height in the BC 20 group. The functionality of all these micronutrients have been described and it is possible therefore that all these factors will contribute to height in growing children.

Nicotinic acid, vit B_6 and folate levels could be used to predict height velocity for the children in the NBC 20 group. Folate is important for normal blood formation and growth in babies and young children. Again it is feasible that these 3 micronutrients can be used to predict height velocity.

At data collection 4 calcium levels could be used to predict height. Since calcium is important for bone formation and this group of children at a stage of rapid growth this finding is not unusual. At data collection 3 there were linear regression relationships between nutrients and body measurements for the total population and or the BC 20 group and NBC 20 group but not at any other time period. Growth rates are thought to be cyclical (Butler *et al.*, 1990) and whilst dietary and breakfast surveys have found no relationship between dietary intake and growth in well nourished populations so far it may be that the

window of time when nutrients might affect growth were missed in the investigative period. Data collection 3 in the present study could have been a growth spurt time for the children.

Overall height and height velocity are more affected by nutrient intake, especially micronutrient intake. This is because optimal skeletal and tissue growth is dependent on many factors and thus these findings highlight the importance of adequate amounts of micronutrients for growth in children. Weight and weight velocity can be predicted by fat, calories and CHO which related not only to increases in triglyceride stores but growth of organs and tissues in this group of subjects.

10 Final Discussion

10. 1 Subject Numbers and Characteristics

The study was a free-living investigation and it was thus an indication of how children attending a breakfast club school might actually behave. However the fluctuation in the numbers of children in each of the BC and NBC groups is one of the major confounding factors of this investigation. In the C.S analysis there were more than double the number of children in the NBC group than the BC group at all time periods Whilst this difference in subject numbers is taken into consideration in the statistical analysis of the results this is a limitation of the study and represents bias towards the NBC group.

The number of children who were analysed for the 3-days of breakfast analysis were greater than the numbers of children analysed for the entire day . This was because there were less completed diaries for the entire day than there were for breakfast only. Also missing data from the baseline line measurement or any subsequent data collection periods has meant that there was also a fluctuation in numbers of children for the change in breakfast from baseline and breakfast at data collections 2,3 and 4 versus the baseline breakfast.

Nutrient intake at breakfast is likely to effect cognitive performance in the short term. Therefore the breakfast eaten on the morning of testing is the crucial measurement and thus the C.S analysis is a valuable tool. The L.S study where subjects were age, sex, height, weight and BMI matched at baseline provided a more scientifically robust analysis of the results. Body measurements are likely to be affected by nutrient intake over a greater space of time than 6 weeks and the L.S analysis has allowed for this to be explored. The cognitive performance of these groups were not different at baseline nor was child behaviour and so these groups were also matched for investigating the effect of breakfast on cognitive performance. The findings from the L.S analysis have in general reinforced the findings of the C.S study .

Despite these 2 sets of analyses there are still many limitations of the data. Whilst the L.S study provides a more scientifically robust analysis of the results the subjects numbers were still relatively small. Due to illness and days off school the number of children in the BC20 and NBC20 group has also fluctuated. One could argue that missing data in such a small matched group will have a bigger impact on the data and the interpretation of the results. Future studies would need be longitudinal in nature to clarify and further examine the differences between children breakfasting at school and those breakfasting at home. The only way to ensure this would be to request that the children at the breakfast club school only ate breakfast at school. The school breakfast would have to become mandatory and part school life like school lunch. Breakfast clubs are becoming well established and they are becoming part of the school ethos and culture. Using a well established breakfast club school in a future research study which has been matched with a school not providing breakfast may allow for a sizable longitudinal study. There are also other limitations to this study and one of the most problematic areas of the data collection was the estimated food diary which is discussed below.

10.1.2 The 3-Day Estimated Food Diary

The study was set in a school environment which allowed the researcher to prompt children to fill in their food diaries. Whilst on the one hand this meant that the children were less likely to forget foods eaten there was also the possibility that they may have altered their eating patterns because they wanted to please the researcher. Measuring dietary intake in humans has many well known difficulties due to behavioural changes. Measuring intake in children also relies on the cognitive ability of each child. The age range and academic ability of the children in the study cannot rule out the fact that some children will have filled in more accurate diaries than others. The MAFF photographic atlas of food portion sizes which was used as a comparison tool is for adults and may not be relevant to the group studied. The comparative study showed that there was no significant difference between school portion sizes and portion sizes estimated by the

children using the food atlas but this was only investigated on a small number of foods. It may not be correct to simply assume that this would apply to all other types of foods. The EI:BMR analysis shows that there was 4% of under-reporting in the C.S investigation and 2% in the L.S analysis. The children were consuming 664.7(±302.4) kcal more than the BMR in the C.S analysis and 722.7(±302.4) kcal more in the L.S analysis. It could be possibility that the children in this study were over-reporting. Measuring physical activity levels would have been a useful tool to investigate whether this number of extra calories is a reasonable amount to fuel the children's activities. Further studies could use heart rate monitors and physical activity diaries to measure food intake.

In the present study it was not possible to carry out a seven-day food diary due to time restraints but further differences between the groups may have been discovered if more dietary data had been collected. A weighed food diary might have given a more accurate analysis of nutrient intake but this may not have given better results due to underreporting (which has been observed in the studies by Bandini *et al.*, 1990, 1997, Livingstone *et al.*, 1992 and Bratteby *et al.*, 1998). The doubly labelled water technique for validation could not have been used in the present study since it is unlikely that parental consent would have been granted. Another confounding factor was that the 3-days of intake did not include a weekend day. However since the study is focusing on the effect of a breakfast club at school the measurement of intake over school days only is entirely applicable. In future studies of this kind where breakfast is the focus it could be recommended that a nutritionist weigh and record the breakfast foods eaten and wasted at the breakfast club to give a truly accurate indication of the consumption. They could also measure intakes at lunchtime in this manner at school. However this would mean that children breakfasting at home or those eating packed lunch would have to record their own intakes and this would introduce bias into the results.

10.1.3 The Effect of the Breakfast Club on Breakfast

There were significantly more cereal consumers in the children eating breakfast at home and significantly greater numbers of cooked breakfast eaters in the children eating breakfast at school. In general the children at the breakfast club were eating significantly more energy than children eating breakfast at home The breakfast club breakfast contained more fat *per se* and at all time periods and for both sets of analysis PUFA and MUFA was higher in the breakfast meal served at school. This was because of the use of 10g of sunflower or olive spread in the hot filled rolls served at the breakfast club and this has a significant impact on increasing calories and these types of fat at the breakfast meal.

CHO but not % energy from CHO was greater in the breakfasts of the BC group at data collection 2 and both the BC and BC 20 groups at data collection 3. On balance sugar and starch was also higher in the children eating breakfast at school due to the consumption of fruit juice and white bread. In general the children were consuming more at the breakfast club than they would at home due variety of foods at a subsidised price. The BC group were eating more calories at breakfast and whilst ensuring that children get enough energy in the morning is important, much of this energy came from fat which is not recommendable when these children have high fat diets.

Ca and vit C intakes were higher for the children eating breakfast at the breakfast club at data collection 2 and 3. The availability of fresh milk and orange juice has had an impact of increasing these 2 micronutrients. Whilst the children consuming breakfast at school were eating cereal with milk, they were consuming on average 150mls of milk with their cereal whilst the BC group were drinking between 1-2 cartons of 225mls of milk. At data collection 4 this difference is not evident since this measurement was taken during the summer months when children at the breakfast club preferred to drink diluting juice in preference to milk and fresh orange juice.

At all data collection points and for both sets of analysis (except for the L.S study at data collection 2), vit A intakes were higher for the children eating breakfast at the breakfast club. The fortification of margarine and increased consumption of milk will have had an impact on increasing the levels of this vitamin in the breakfasts of the BC and BC 20 groups. Vitamin D intakes are also higher for the BC 20 group at data collections 3 and 4 and again fortification of margarine will have increased the levels of this vitamin.

10.1.4 Nutritional Guidelines for Breakfast

As yet there are no nutritional guidelines in England or Scotland for breakfast served at school. There are no set guidelines for breakfast consumption in general although in practice health professionals recommend that 20% of energy and nutrients come from this meal with 30% from lunch and dinner and the remainder from snacks. School breakfast programs (SBP) breakfasts in the U.S are required to provide approximately 25% of the RDA for important nutrients over a period of time (protein, ca, Fe, vit A, vit C and calories). In addition regulations now require that all school meals meet the recommendations of the 1995 Dietary Guidelines for Americans.

To achieve both the RDA and the Dietary Guideline standards, schools may use several methods for planning menus. One way is to prepare meals using food-based menu planning. A school breakfast using the food-based menu planning approach must contain , at a minimum, the following food components:

- A serving of fluid (whole or low fat milk served as a beverage or on cereal or used in part for each purpose
- A serving of fruit and vegetable or both, or undiluted fruit or vegetable juice
- Two servings from one of the following components – bread/bread alternative or meat/meat alternative: alternatively, there can be one serving from each component.

The guidelines for school lunches in Scotland have been outlined in chapter 1.3.1, where recommendations are that lunch should provide 30% of energy for the day, and should

have no more than 35% of food energy from fat , SFA should constitute no more than 11% of food energy , CHO not less than 50% of food energy , NME (non-milk extrinsic) sugars not more than 11% of food energy , Fibre/NSP (non-starch polysaccharides) not less than 30% , protein not less than 30% of RNI, no less than 40% of Fe, RNI Calcium at least 35% of RNI for Ca , not less than 30% of RNI for vit A, not less than 40% of RNI for folate , not less than 35% of RNI for vit C , no more than 30% of RNI for sodium , and 1/3 of 5 portions per day for fruit and vegetables. These guidelines may be hard to achieve . Breakfast served at school may be the perfect opportunity to increase micronutrient levels especially. A fortified breakfast cereal with milk and orange juice will keep the breakfast meal low fat and nutrient dense. Guidelines for lunch could therefore go hand in hand with breakfast to provide a healthy start to the day followed by a healthy lunch.

Whilst SBP regulations require that school breakfast provide one-quarter of the RDA for calories, the breakfast offered in school may fall short (Dwyer, 1996). Previous research into SBPs in the U.S has shown a number of differences between the breakfasts served at school an those served a school. SBP participants have higher intakes of energy, protein, thiamine, riboflavin, phosphorous, magnesium, and Ca than non–participants (Devaney *et al.,* 1993). Nicklas found that breakfasts served at school contain more calories, protein and CHO (specifically lactose) and sodium than those served at home. The present research is in-line with these findings and whilst sodium was not measured it is likely that levels would be higher in children breakfasting at school due to the consumption of bacon, sausage and white bread. Breakfast cereals provide just 8% sodium in a child's diet, compared to 22% from meat & meat products, 14% from white bread, 7% from milk & milk products, 6% from vegetables and 6% from savoury snack (NDNS, 2000). On the other hand Nicklas (1998) found that breakfast served at home contain more sucrose, total fat (especially SFA), and dietary cholesterol than those served at school. He also found

that a larger percentage of subjects eating breakfast at home did not meet two-thirds of the RDA for vitamins A and D, Ca, magnesium, thiamine, riboflavin, and zinc than those eating breakfast at school. Dywer *et al.* (1998), however, did not find any major differences in nutrient intake between breakfasts eaten at home, at school, or in both of these places, with the exception of Fe intake. School breakfasts contributed on average , significantly less iron than did home breakfasts. This was not a finding of the present research.

From 1981-1988, the percentage of calories from protein and CHO increased in school breakfast, while the percentage of calories from fat and cholesterol decreased (Nicklas 1998). The increase in CHO intake may be attributable to a greater consumption of cereal and fruit. Children were also more likely to drink reduced-fat or low-fat milk fat milk rather than whole milk at school (Nicklas, 1998; and American Dietetic Association 1999). It is likely that total fat intakes would increase in children attending a U.K breakfast club if nutritional guidelines are not set, since children in this study we have found that children preferentially eat a cooked breakfast. The CHO intake in the children breakfasting at school was higher in the present study due to the consumption of white bread rolls and sugar intakes were higher due to the availability of juices and hot chocolate. However the results of the present study do mirror the findings by Nicklas in that children at the breakfast club were more likely to drink fat reduced milk than this breakfasting at home.

An American study by Worobey and Worobey (1999) found that 4-year old children increased calories from complex CHO from home breakfast (baseline) to a SBP school breakfast (treatment), whilst calories from refined sugar showed the opposite, decreasing under the school breakfast condition. This was not the case in the present study, with the increase in PUFA and MUFA being the reason for the increase in calories.

Eating a well-balanced breakfast should be easier in theory to administer in a school setting and should reflect healthy eating practices as taught in the national curriculum..

However without nutritional guidelines a school breakfast may detrimentally affect intakes at breakfast. Whilst the present study shows that intakes of Ca, vit C, A and D were all higher in children receiving breakfast at school due to high consumption of milk, fresh orange juice and fortified margarine, intakes of the B-vitamins at breakfast were lower than those eating a 'normal' RTEBC breakfast at home. Hot filled rolls served at the breakfast club increased calories from fat and the 10g sunflower/olive spread in these increased amounts of PUFA and MUFA.

On the basis of results of this study nutritional guidelines for breakfast should be recommended so that breastfast and lunch work together. It is important that children consume something in the morning and a hot filled roll may be a much needed substantial breakfast for poorer children . However if as this study suggests they are likely to consume a fatty lunch and evening meal the breakfast meal may be a perfect opportunity to give them a 'healthier' start to the day.

A breakfast that provided; 30% of energy for the day, with not more than 15 % fat, not less than 15% protein, and approximately 70% carbohydrate (at least 45 % of which should be starchy carbohydrates) and not less than 25% of the RNI for Fe, Ca, Vit A, Vit C and B-vitamins may be a reasonable goal. Food components could include:

- cereal and toast (with a maximum of 5g of margarine or butter)

- at least one serving (250ml) of whole or semi-skimmed milk

- at least one serving of fruit or fresh orange juice

This recommendation for a very high carbohydrate breakfast (70%) with only a 15% fat content may mean that children eat within healthy guidelines for the day i.e. eating a school breakfast and school lunch will give them a healthier start to the day . If children have a healthier start to the day by eating a breakfast and lunch which is within healthy

eating recommendations it is likely that their consumption for the day is also likely to be close to these recommendations. The healthy eating education which is part of the school curriculum should be reflected in what is eaten at breakfast and lunch at school for a fully integrated approach.

10.1.5 The Effect Of Breakfast on Daily Intake

Whilst there was no statistical difference in percentage energy from fat between the groups , children in the breakfast club had a higher % energy from fat for the day. Whilst both groups were above the recommended 35% energy from fat the BC and BC20 group averaged 43% and 42% as compared to the NBC and NBC 20 groups (38% and 37%).PUFA and MUFA intakes were higher for the BC and BC 20 groups at breakfast and were higher in these groups when total day intakes of these fats were examined. Given concerns about excess intakes of fat, studies on the impact of RTEBC on children's dietary intakes are of interest. Studies have examined the extent to which RTEBC consumption is related to intakes of fats, vitamins and minerals. National data from the U.S from 1981-1991 indicate that RTEBC, which are generally fortified with nutrients, are significant contributor to daily nutrient intake because of both their nutrient content and the relative frequency of cereal consumption by children (Subar *et al.,* 1998). RTEBC were found to be major contributors to children's energy, CHO, and fibre intakes as well as intakes of most vitamins and minerals. Data from the Child and Adolescent trial for Cardiovascular Health in the U.S found that breakfast cereals provided 27% of dietary Fe in children aged 6-11 years. In addition, cereals are often consumed with milk, which in turn, increases the intake of energy , Ca and other nutrients such as vitamins A and D.

Seven-day food diaries collected for the Bolgalusa Heart Study revealed that children who ate RTEBC at breakfast at least three times over a period of one week consumed significantly less fat and cholesterol and significantly more fibre, B-vitamins, vits A and D than those who did not eat cereal at breakfast (Nickals *et al.*, 1994).

At data collections 2 and 3 the BC and BC 20 group had higher intakes of vit C and Ca due to the consumption of orange juice and milk. These differences persisted between the groups when total day intake was examined. This implies that these particular foods at breakfast can impact on micronutrient status for the day. Ca intakes are traditionally high at breakfast because RTEBC are consumed with milk (Nicklas, 1998), whilst the finding that orange juice contributes to vit C intake is in-line with findings from the NDNS (NDNS, 2000). These drinks should therefore be encouraged at breakfast clubs.

10.1.6 The Contribution of Breakfast To Daily Nutrient Intake

Although studies of the nutrient effects of eating breakfast vary considerably in the study populations and data sets used, a consistent finding of these studies is that breakfast makes a significant contribution to nutrient intake over 24 hours. The first National Evaluation of the School Nutrition Program in the U.S showed that eating breakfast was significantly and positively related to the daily intake of all nutrients examined (Devaney and Fracker 1989). Later studies of breakfast consumption patterns of children also found that total daily intakes of food energy and other nutrients were significantly lower for children who did not consume breakfast compared with children who did, and that children who missed breakfast did not make up the difference in nutrient intakes at other meals (Nicklas *et al.*,1993 and Sampson *et al.*, 1995).

The breakfast of the children who ate this meal at the school breakfast club contributed a greater amount of calories than those who ate it at home. Breakfasts of children eating breakfast at school contributed between 12-20% of energy intakes, whilst children the breakfast meal eaten at home contributed 12-14% for energy. At data collection 3 the fat content of the breakfasts eaten at school contributed significantly to fat intakes for the day for both the C.S and L.S study. This is a worrying finding bearing in mind that health care professionals advocate that a healthy breakfast should be low in fat. The margarine used at the breakfast club contributed significantly to intakes of PUFA and MUFA for the children

at the breakfast club. CHO intake at the school breakfast also contributed significantly to total CHO intakes for the day when compared to the breakfast consumed at home.

Further studies could look at breakfasts that were in-line with healthier school breakfast guidelines versus a breakfast that did not reach these recommendations and how this intake in the morning affected intake throughout the day.

10.1.7 Cognitive Test Performance

There were improvements in cognitive performance for the children eating breakfast at school in both the C.S and L.S study from baseline to data collections 3 and 4.This improvement was not as pronounced as in the children continuing to eat breakfast at home. The children eating breakfast at school appeared to reach a plateau in score improvement at data collection 3, whilst children at home showed a pronounced improvement in scores from baseline to data collection 3 and baseline to data collection 4.

The C.S study revealed more improvements than the L.S study which would be expected due to the greater numbers of children in the NBC group versus the BC group. We cannot ignore the fact that the greater improvements seen in the C.S are due to the data analysis rather than the improvement in scores alone. Whilst the associations between nutrient intake and cognitive performance scores have been explored there are other factors to take into consideration. Much of the previous research into breakfast and cognitive performance has been quasi-experimental in design in that it has some of the features of an experimental design, but does not control for all potentially confounding factors (Pollitt and Matthews , 1998). Lack of effect of the breakfast condition of the breakfast studies by Dickie and Bender, 1982, Lopez *et al.*, 1993 and Vaisman *et al.*, 1996 have been criticised due to confounding factors.

One of the confounding factors in the present study was timing of cognitive function testing. Children who ate breakfast at school were tested anytime form 15 minutes to 2 hours after consuming breakfast. However children who ate breakfast at home tended to eat breakfast earlier and so were tested 30 minutes – 2 hours. Whilst the time of breakfast

consumption was recorded in the diet diaries and the order for testing the children was kept the same at each data collection period, it was not possible to standardise the time of cognitive performance testing. Data was collected by the author only and if there were more resources or another way of measuring the children all together (i.e. a computer test) then it would have been possible to eliminate some of the effects of timing on cognitive test performance. For future studies the time at which children ate breakfast at home could be noted by parents or guardians. One Israeli study found that 11-13 year –old elementary children who routinely eat the usual Israeli breakfast did not perform better in cognitive performance tests than those who start the day without breakfast when studies 1.5 hr to 2 hrs later (Vaisman *et al.,* 1996). Food supplementation 30 mins prior to testing however notably improved scoring.

Studies in animals and humans show that an increase in glucose concentrations prior to or immediately after a learning session improves cognitive functions and memory skills (Manning *et al.,* 1994). Previous research has indicated a reversed-U-shaped glucose curve for the process of improving memory skills (Parsons *et al.*, 1992). Low doses were without effect, intermediate doses enhance memory, and higher doses either have no effect or impair memory. Optimal glucose enhancement of memory storage in rats is seen at doses (e.g., 100mg/kg) which results in elevations in blood glucose levels from 120 to 160 mg/L (Hall and Gold 1986). Vaisman *et al.* (1996) proposed that there were no improvements in his group of school children because the effect of an increased glucose concentration may be indistinguishable when testing is performed 2 hours after the meal; however performance improved notably when subjects ate a meal shortly before being tested when raising glucose levels may facilitate memory.

In the present research the children who did better in cognitive performance tasks were the children who continued to eat breakfast at home. There were significantly more RTEBC eaters in this group than the children in the BC/BC20 group. Also the time between when breakfast was eaten and when the children breakfasted at home were tested was in general

a longer time then the time between breakfast and testing of the school breakfast group. The control of blood glucose and insulin levels depends on the starch and non-starch polysaccharide contents of the meal (Cummings *et al.*, 1995), which is known as the glycaemic index (G.I) of foods (Jenkins *et al.*, 1981). It was not possible to measure the G.I of the breakfasts which may have been a useful tool to support the theory that the children eating breakfasts at home had a meal with slower release CHOs which facilitated cognitive performance. G.I is however an evolving area of science (e.g. adding fat and milk will lower the G.I of a meal and so the children at the breakfast club may hypothetically have breakfasts that were lower G.I than children eating breakfast at home). Whilst measuring the G.I would have been interesting to investigate this may not have offered any further reasons for the marked increase in scores for the NBC and NBC 20 group only. Research by Benton provided evidence that low GI breakfast allows better cognitive performance (Benton *et al.*, 2003). The meal that produced a smaller increase in blood glucose was associated with better memory. However a recent study by the same group failed to support this finding and a higher GI breakfast was associated with better memory (Benton, personal communication 2004). Benton concluded that future work should consider the interaction between individual differences in glucose tolerance and the glycaemic stimulus of the meal, i.e. better glucose regulation may be associated with better cognitive functioning. It would have been ideal to measure individuals responses to a glycaemic load but measuring blood glucose levels and insulin responses would not have possible in this investigation .

Whilst girls in the present study showed more pronounced improvements in scores than the boys and better glucose regulation may be a reason for this they may well have been more motivated. The teacher behaviour report forms which measured aspects of motivation at the baseline measurement did not highlight this but since the researcher was also female the rapport that was build between the girls and the investigator may have had an impact on behaviour. Another major confounding factor in the study was the test-retest stability

of the cognitive performance scores. It is well-established that practice effects are greater after short intervals. Test re-test stability has been measured with the WISC-III^{uk} over a 2-9 week period. Practice effects are smaller over longer test-re-test intervals. On average children were re-tested 5-7 weeks apart and so test-re-test stability cannot ignored. However since both groups are being compared to their baseline measurement re-test stability is a confounding factor for both groups and so they may still be compared to one another.

The very fact that the researcher was there to observe the children's academic cognitive performance may have an impact on the scores achieved. Also whilst the tests were chosen to measure certain facets of cognitive performance that have been shown to be affected by nutrient intake it cannot be completely ruled out that these tests were the most sensitive or appropriate for this study.

The tests used in the study measured sustained memory or vigilance (coding subtest), immediate memory (digit span) and arithmetic (mental computation and reasoning). Whilst we must taken these confounding factors into consideration there is still evidence to suggest that school learning may be improved in the long term by the NBC and this could in turn have an impact on academic performance. Further investigations would need a more rigorous methodology to ensure that all the confounding factors were minimalised. A cereal breakfast typical of that consumed by the NBC group could be administered within a school setting at the same time as the typical school breakfast consumed by the BC group. Both these breakfasts could be accurately weighed and recorded by researchers and a battery of computerised tests that measured many facets of cognitive performance could be given to the children in a class setting in the first lesson. A trained observer could be used in the class room observe classroom behaviour.

10.1.8 Cognitive Performance and Breakfast Nutrient Correlations

There were correlations between test performance and carbohydrates and some of the B-vitamins. As discussed in the literature review there has been a plethora of research to show the improvement of cognitive performance after administration of glucose (Benton *et al.,* 1987, 1989, 1990, 1995, 1999, Conners *et al.,* 1984, Foster *et al.,* 1998) and recent evidence by Wesnes revealed that blood glucose levels following cereal consumption lead to improved memory as compared to other types of breakfast (Wednes, 2003). Since CHO foods are readily digested and metabolised to produce glucose the brain's preferred metabolic fuel, this could provide an explanation for the positive association . The mechanisms being by which glucose effects cognitive function are that glucose is a precursor for acetylcholine and it is a also produces ATP. Glucose may also have an effect on neutrotransmitters such as ephinephrine.

Coding seems to be the one test score that is the most sensitive to levels of CHO. This task is a measure of sustained attention and psychomotor speed and it could be that glucose levels in certain localised areas of the brain are required at particular levels for this task. One would expect arithmetic to be less sensitive to brain glucose levels since to some extent these skills are learnt. The digit scan score which is an example of immediate auditory memory appeared to be correlated to fat, PUFA, MUFA, SFA for the NBC groups at data collections 2 and 3. The data analysis examined the correlation between one factor and another . Whilst correlations between specific nutrients and cognitive tests were found it is purely an examination of the association of one factor with another. The specific relationship and interaction between these two factors is difficult to determine and whilst correlations of this type are useful indication of the nature of the relationship there is no indication of the mechanisms by which the two factors are associated. Further investigations should aim to look at how these factors may be related which may involve more invasive procedures such as blood analysis.

On balance it appears that high-fat meals are likely to increase subsequent fatigue and reduce reported alertness, but with little effect on cognitive performance relative to high-CHO-low-fat meals (Dye *et al.*, 2002). Whilst fat may affect alertness this would not be a consideration in this study since lipids from a meal are not likely to reach the duodenum in substantial amount until 2-3hrs after ingestion (Wells *et al.,* 1995). The possible relationship between micronutrient intake and cognitive performance has not been an area of focus in this research because micronutrient intakes are likely to affect malnourished and undernourished populations over a period of time. The children in this study were well nourished. However the link between vitamin and mineral supplementation in healthy children and cognitive performance has been an area of interest for many years. On balance there has been no evidence that learning ability was limited by the quality of micronutrients in the diets of well nourished British school children and that there were no consistent correlations between test scores and micronutrient intakes based on weighed records (Nelson *et al.*, 1990). There is no doubt that intelligence and academic performance are affected by nutritional stats as is the evidence from undernourished children (Pollitt, 1990). However the level of undernutrition that must exist before academic performance is affected still remains to be answered (Nelson, 1992).

Nutritional anaemia is one of the most common diet related deficiency disorders and Anaemia carries implications for both mental and physical performance(Buttriss 2002). Whilst it was not possible to measure haemoblogin levels in this group of children it is likely that some children may have had some form of (sub clinical) mild iron deficiency anaemia. In the NDNS of young people, 13% of all boys and 14% of all girls had low iron stores (as indicated by plasma ferritin levels), (Buttriss 2002). Moderate to severe iron deficiency anaemia in children leads to reduced cognitive function, which can be improved by iron supplementation. Deinard et al, (1985). A new British survey among almost 600 girls aged 11-18 years has found that mild iron deficiency anaemia can also affect cognitive function IQ scores in girls with poor iron status were significantly lower than in

girls with borderline or good iron status and only iron status and social class were significant predictors of IQ score (Ash and Nelson *in press*). Even in the absence of clinical signs, poor iron status is associated with lower cognitive function in teenage girls (Buttriss , 2002). Fe intakes in this group were at times below the RNI and the established link between cognition and Fe could have been a explanation for low cognitive performance in some children.

10.1.9 Anthropometry

There were no differences between the children who ate breakfast at school and those who ate breakfast at home for body measurements. Whilst anthropometric measurements were taken for the children data was only analysed for the L.S study since children stayed in the same group throughout the study and food intake is likely to have an effect on body measurements over a period of time.

There was no difference in growth, weight gain or body composition of the children. Only a few studies have shown an improvement in children's nutritional status by way of a increase in growth velocity with school feeding and these are in developing countries where improved nutrient status has had a positive effect on growth in undernourished children (Grantham-McGregor *et al.* 1998, Paige *et al.*, 1976, Argarwal *et al.*, 1987, Lancet *et al.*, 1928, Leighton *et al.*, 1929, Lininger *et al..*, 1933). There has been no such evidence in well nourished populations. This is because they are rarely deficient of the nutrients necessary for growth.

As described in Chapter 9.1 the children in this study were slightly taller than those in Hughes study of 2000-3500 Scottish school children and they were also heavier supporting the evidence that children are getting taller and heavier at each generation. The equation used for determining FFM in the present study was age and sex specific. The prediction equation used has been cross-validated against densitometry, anthropometry and is specific for children under the age of 15 (Deurenberg *et al.*, 1991). The intercept of

the regression equation FFM = a x H^2/R + b was found to be age, (and at older ages) sex dependent, increasing from age 7 to 15, and slowly decreasing after 16. There were 62 children in the age 7-10 group in the Deurenberg study and FFM was 23.7(± 3.)kg. At baseline FFM for the BC20 group was 23.6± 0.6 and 22.8 ± 0.9 for the NBC20 group. Mean FFM for the BC20 group after the start of the breakfast club was 24.1kg whilst it was 23.1kg. These findings are in-line with the findings of Deurenberg. However % body fat was higher than. In the Deurenberg *et al.* (1989) study of pre-pubescent children where he found FFM to be 24.1kg for 8-11 year old children and that % body fat was 21.6kg. Percentage body fat for the BC 20 in the present study was 25.9%, and was 26% NBC 20.

Whilst none of the children in the longitudinal study were overweight these increases in % body fat is a worrying trend. The measurement of body fat in Hughes study (Hughes *et al.*,1997) also showed that there was an increase in both the English and Scottish group examined but fatness was slightly higher in the Scottish group. The researchers suggested that this indicated a trend towards obesity in Scottish school children particularly.

Whilst BIA is a now a well known tool for measuring body composition in children, it has been questioned whether fat-free mass (FFM) is a reliable measure of the cross-sectional area of the body in growing children (Deurenberg *et al.,* 1989).From data from another study in children (Deurenberg *et al.,* 1990) it could be calculated that the relative increase in cross-sectional arm area, waist area and hip area (calculated from circumferences) from age 7 to 20 was 80-90 per cent of the relative increase in FFM. Only CT-scans of the total body could provide a valid estimate of the mean cross-sectional area of the body , but in a study of Baumgartner, Chumlea and Roche (1989) it was shown that total body impedance of the extremities, thus the cross-sectional area of the arm and leg are probably more important than the cross-sectional trunk area. Nevertheless the use of the specific impedence in growing children could still be criticized.

Skin-fold callipers may have been another method that could have been used to measure body composition but again this method may not have been acceptable for parents and children, since it is quite an invasive procedure for children.

The results of the present research have not been compared with U.K standards for height, weight and BMI (Freeman *et al.,* 1995) since this was not an aim of the thesis and it is unlikely that a group of 40 Edinburgh primary school children will show relevant or meaningful comparisons with the UK population standard sample. However the range of heights, weights and BMI of the present study are within the range of the heights, weights and BMI of the U.K standards, so we can conclude that whilst not representative of the U.K population, this group of children are within the 'normal' range. Whilst it was not within the parameters of the thesis to look at nutrient intake and body composition of overweight children his would be an interesting area to focus on with the present data.

10.2 The Relationship Between Dietary Intake and Anthropometric Measurements

There were associations between nicotinic acid and height velocity. Relationships existed between vitamin C and weight also. Fat and weight velocity were associated. Linear regression analysis also showed an association between vit A and weight velocity, Ca, nicotinic acid, vit D and height, calcium and height, for the total population of children in the L.S study. There were no relationships between nutrient intake and anthropometric measurements for the groups when analyses separately apart from at data collection 3, where CHO and weight velocity were related for the BC 20 group, whilst calories and weight velocity were associated for the NBC 20 group. Ca, vit C, B_2, nicotinic acid, vit D and height were related for the BC 20 group also at data collection 3, whilst nicotinic acid, folate and height velocity were related to height velocity for the NBC 20 group. Whilst the associations between almost all nutrients and growth have explanations(see chapter 9.2), growth rates are thought to be cyclical (Butler *et al*, 1990). Data collection 3 (March/April 2001) could have reflected group spurts in the children. Whilst dietary

intake and growth in these children have shown some relation in this study other factors affecting growth such as growth hormones and genetic factors need also to be taken into consideration before any definite conclusions can be made about the relationship of nutrient intake and growth in children. Growth in children is cyclical and future studies may have to follow up children for longer than a year i.e. for a period of 2-3 years. However in order to determine how diet effects children it would be necessary to investigate children starting from a younger age i.e. 5 years old to order to the onset of puberty. However investigating food intake in children of that age would mean parental involvement which would introduce bias.

The different breakfasts and diets of the BC 20 and NBC 20 group had no impact on body measurements. Whilst relationships between nutrient intake and growth were found for the total population of children in the L.S study, there were few difference between the groups. In well nourished populations therefore the intervention of a breakfast club does not affect body composition in children.

CONCLUSION

Breakfast clubs in the U.K were first introduced to improve the diets of British school children. However without nutritional guidelines to regulate the nutritional content of this meal it is unlikely that this primary objective will be reached. The present research has provided evidence that the availability of hot filled rolls served at a breakfast club at school will increase energy , fat, PUFA and MUFA in the breakfasts and diets of Scottish primary school children. Since the 1993 Scottish-Diet Report (1993) , the Scottish diet has been under heavy scrutiny. The report revealed that children were following a diet similar to that of Scottish adults, which was one that was high in fat, and low in vegetables of all kinds. It quoted that' the usual Scottish diet consumed by children is also that which would now be conducive to the development of adult chronic disease.'

Guidelines for breakfast at school should recommend that this meal provides 30% of energy for the day and that it should be high CHO (70% carbohydrate with at least 45% starchy CHO) with a fat content of not more than 15%. School breakfast and school lunch guidelines should go hand in hand so that together they ensure a healthier start for children and therefore they are more likely to reach healthy eating recommendations by the end of the day. For a fully integrated approach the healthy eating education in the school curriculum should match what is practised at school breakfast and lunch.

Breakfast in this study provided 16-20% of energy intakes for the day reinforcing the importance of the contribution of this meal to daily energy intakes. There was compensation of overall energy intakes when children ate a higher energy breakfast.

Children who predominantly consume cereal breakfasts at home had a meal that was lower in fat, higher in starch and consumed a breakfast that was more B-vitamin dense (up to 40% of the RNI) than those children who ate breakfast at the school breakfast club. The children who ate breakfast at home did significantly better in cognitive performance than children who ate breakfast in school. Associations between % energy from starch

form breakfast and cognitive function scores were found, supporting that CHO foods are readily digested and metabolised to produce glucose the brain's preferred metabolic fuel. The children who ate their habitual breakfast at home performed better in tests of sustained memory, immediate memory and mental computation and reasoning there is therefore evidence to suggest that school learning may be improved in the long term in this group also and this could in turn have an impact on academic performance.

The children were taller and heavier than those in a national growth survey (Hughes *et al.*,1997) and this finding supports the evidence that children in developed countries are getting taller and heavier. However the percentage body fat of these children was also higher which is cause for concern. Calorie and CHO intake were related to weight velocity whilst Ca and some of the B-vitamins were related to height velocity.

This research demonstrates that nutrient guidelines for breakfast clubs at school should be implemented. A high complex CHO, lower fat breakfast such as fortified cereals will not only help to ensure that children's diets are closer to government guidelines but may help school learning and concentration by supplying a steady supply of glucose to the brain.

References

Achenbach, T. M. 1978, "The Child Behavior Profile: I. Boys aged 6--11", *J Consult Clin Psychol*, vol. 46, no. 3, pp. 478-488.

Achenbach, T. M. & Edelbrock, C. S. 1978, "The classification of child psychopathology: a review and analysis of empirical efforts", *Psychol Bull*, vol. 85, no. 6, pp. 1275-1301.

Achenbach, T. M. & Edelbrock, C. S. 1984, "Psychopathology of childhood", *Annu Rev Psycho*, vol. 35, pp. 227-256.

Acheson, K. J., Campbell, I. T., Edholm, O. G., Miller, D. S., & Stock, M. J. 1980, "The measurement of food and energy intake in man-an evaluation of some techniques", *Am J Clin Nutr*, vol. 33, no. 5, pp. 1147-1154.

Adamson, A., Rugg-Gunn, A., Butler, T., Appleton, D., & Hackett, A. 1992, "Nutritional intake, height and weight of 11-12-year-old Northumbrian children in 1990 compared with information obtained in 1980", *Br J Nutr* vol. 68, no. 3, pp. 543-563.

Albertson, A. M. & Tobelmann, R. C. 1993, "Ten-year trend of energy intakes of American children ages 2-10 years", *Ann N Y Acad Sci.*, vol. 699, pp. 250-252.

Amiel, S. A., Pottinger, R. C., Archibald, H. R., Chusney, G., Cunnah, D. T., Prior, P. F., & Gale, E. A. 1991, "Effect of antecedent glucose control on cerebral function during hypoglycemia", *Diabetes Care*, vol. 14, no. 2, pp. 109-118.

Anderson, A. S., Macintyre, S., & West, P. 1994, "Dietary patterns among adolescents in the west of Scotland", *Br .J Nutr*, vol. 71, no. 1, pp. 111-122.

Austin, G. E., Wheaton, R., Nanes, M. S., Rubin, J., & Mullins, R. E. 1999, "Usefulness of fructosamine for monitoring outpatients with diabetes", *Am J Med Sci*, vol. 318, no. 5, pp. 316-323.

Baddeley, A. & Wilson, B. A. 2002, "Prose recall and amnesia: implications for the structure of working memory", *Neuropsychologia*, vol. 40, no. 10, pp. 1737-1743.

Ball M 1998, *School Inclusion; the school, the family and the community,* The Joseph Rowntree Foundation, York.

Bandini, L. G., Schoeller, D. A., Cyr, H. N., & Dietz, W. H. 1990, "Validity of reported energy intake in obese and nonobese adolescents", *Am J Clin Nutr*, vol. 52, no. 3, pp. 421-425.

Bandini, L. G., Cyr, H., Must, A., & Dietz, W. H. 1997, "Validity of reported energy intake in preadolescent girls", *Am J Clin Nutr*, vol. 65, no. 4 Suppl, pp. 1138S-1141S.

Baranowski, T. & Domel, S. B. 1994, "A cognitive model of children's reporting of food intake", *Am J Clin Nutr*, vol. 59, no. 1 Suppl, pp. 212S-217S.

Baric I.C, Cvjetic S, & Satalic Z 2001, "Dietary Intakes Among Croatian Schoolchildren and Adolescents", *Nutrition and Health*, vol. 15, pp. 127-138.

Baric I.C & Satalic Z 2002, "Breakfast Quality Differences among Children and Adolescents in Croatia", *International Journal Of Food Sciences and Nutrition*, vol. 53, pp. 79-87.

Barkley, R. A. 1990, "A critique of current diagnostic criteria for attention deficit hyperactivity disorder: clinical and research implications", *J Dev Behav Pediatr.*, vol. 11, no. 6, pp. 343-352.

Bartus, R. T., Dean, R. L., III, Beer, B., & Lippa, A. S. 1982, "The cholinergic hypothesis of geriatric memory dysfunction", *Science*, vol. 217, no. 4558, pp. 408-414.

Baumgartner, R. N., Chumlea, W. C., & Roche, A. F. 1989, "Estimation of body composition from bioelectric impedance of body segments", *Am J Clin Nutr*, vol. 50, no. 2, pp. 221-226.

Beck, A. T., Brown, G., Steer, R. A., Eidelson, J. I., & Riskind, J. H. 1987, "Differentiating anxiety and depression: a test of the cognitive content-specificity hypothesis", *J Abnorm Psychol*, vol. 96, no. 3, pp. 179-183.

Beertema, W., van Hezewijk, M., Kester, A., Forget, P. P., & van Kreel, B. 2000, "Measurement of total body water in children using bioelectrical impedance: a comparison of several prediction equations", *J Pediatr Gastroenterol Nutr*, vol. 31, no. 4, pp. 428-432.

Bellisle F, Blundell J.E, Fantion M, Fletcher, R., & Lambert J 1998, *Functional food science and behaviour and psychological functions.*

Benton P, Owens D.S, & Parker P.Y 1994, "Blood Glucose Influences Memory and Attention in Young Adults", *Neuropsychologia*, vol. 32, pp. 595-607.

Benton, A. L. 1975, "Developmental dyslexia: neurological aspects", *Adv Neurol*, vol. 7, pp. 1-47.

Benton, D., Brett, V., & Brain, P. F. 1987, "Glucose improves attention and reaction to frustration in children", *Biol Psychol*, vol. 24, no. 2, pp. 95-100.

Benton, D. & Roberts, G. 1988, "Effect of vitamin and mineral supplementation on intelligence of a sample of schoolchildren", *Lancet*, vol. 1, no. 8578, pp. 140-143.

Benton, D. 1990, "The impact of increasing blood glucose on psychological functioning", *Biol Psychol*, vol. 30, no. 1, pp. 13-19.

Benton, D. & Sargent, J. 1992, "Breakfast, blood glucose and memory", *Biol Psychol*, vol. 33, no. 2-3, pp. 207-210.

Benton, D. & Owens, D. 1993, "Is raised blood glucose associated with the relief of tension?", *J Psychosom Res*, vol. 37, no. 7, pp. 723-735.

Benton, D. & Owens, D. S. 1993, "Blood glucose and human memory", *Psychopharmacology*, vol. 113, no. 1, pp. 83-88.

Benton, D. & Parker, P. Y. 1998, "Breakfast, blood glucose, and cognition", *Am J Clin Nutr*, vol. 67, no. 4, pp. 772S-778S.

Benton, D., Ruffin, M. P., Lassel, T., Nabb, S., Messaoudi, M., Vinoy, S., Desor, D., & Lang, V. 2003, "The delivery rate of dietary carbohydrates affects cognitive performance in both rats and humans", *Psychopharmacology* , vol. 166, no. 1, pp. 86-90.

Biessels G.J 1999, "Cerebral complications of diabetes: clinical findings and pathogenic mechansims", *Neth J Med*, vol. 54.

Bingham S 1989, "Aspects of dietary survey methodolgy", *BNF Nutrition Bulletin*, vol. 10, pp. 90-108.

Bingham, S. A., Williams, R., Cole, T. J., Price, C. P., & Cummings, J. H. 1988, "Reference values for analytes of 24-h urine collections known to be complete", *Ann Clin Biochem*, vol. 25 (Pt 6), pp. 610-619.

Bingham, S. A., Gill, C., Welch, A., Day, K., Cassidy, A., Khaw, K. T., Sneyd, M. J., Key, T. J., Roe, L., & Day, N. E. 1994, "Comparison of dietary assessment methods in nutritional epidemiology: weighed records v. 24 h recalls, food-frequency questionnaires and estimated-diet records", *Br J Nutr*, vol. 72, no. 4, pp. 619-643.

Black A.E, Goldberg G.R, Jebb S.A, Livingstone M.B.E, Cole T.J, & Prentice A.M 1991, "Critical evaluation of energy intake data using fundamental principles of energy physiology:2. Evaluating the results of published survey", *Eur J Clin Nutr*, vol. 45, pp. 583-599.

Black, A. E., Bingham, S. A., Johansson, G., & Coward, W. A. 1997, "Validation of dietary intakes of protein and energy against 24 hour urinary N and DLW energy expenditure in middle-aged women, retired men and post-obese subjects: comparisons with validation against presumed energy requirements", *Eur J Clin Nutr*, vol. 51, no. 6, pp. 405-413.

Blom L, Lundmark K, Dahkquist G, & Persson L A 1989, "Estimating children's eating habits", *Acta Paediatr Scand*, vol. 78, pp. 858-864.

Booth, P. J., Craigon, J., & Foxcroft, G. R. 1994, "Nutritional manipulation of growth and metabolic and reproductive status in prepubertal gilts", *J Anim Sci.*, vol. 72, no. 9, pp. 2415-2424.

Boreham, C., Savage, J. M., Primrose, D., Cran, G., & Strain, J. 1993, "Coronary risk factors in schoolchildren", *Arch Dis Child*, vol. 68, no. 2, pp. 182-186.

Borrelli, R. 1990, "Collection of food intake data: a reappraisal of criteria for judging the methods", *Br J Nutr*, vol. 63, no. 3, pp. 411-417.

Box V & Landman J 1994, "A breakfast survey of primary schools in low income inner city areas of Southampton", *Health Education Journal*, vol. 53, pp. 249-267.

Bratteby, L. E., Sandhagen, B., Fan, H., Enghardt, H., & Samuelson, G. 1998, "Total energy expenditure and physical activity as assessed by the doubly labeled water method in Swedish adolescents in whom energy intake was underestimated by 7-d diet records", *Am J Clin Nutr*, vol. 67, no. 5, pp. 905-911.

Bray, G. A., Greenway, F. L., Molitch, M. E., Dahms, W. T., Atkinson, R. L., & Hamilton, K. 1978, "Use of anthropometric measures to assess weight loss", *Am J Clin Nutr*, vol. 31, no. 5, pp. 769-773.

Brioni, J. D., Nagahara, A. H., & McGaugh, J. L. 1989, "Involvement of the amygdala GABAergic system in the modulation of memory storage", *Brain Res*, vol. 487, no. 1, pp. 105-112.

Brody, S. & Wolitzky, D. L. 1983, "Lack of mood changes following sucrose loading", *Psychosomatics*, vol. 24, no. 2, pp. 155-2.

Brook C.G.D. 1971, "Determination of body composition of children from skinfold measurements", *Arch Dis Child*, vol. 46, pp. 182-184.

Bryan, J., Calvaresi, E., & Hughes, D. 2002, "Short-term folate, vitamin B-12 or vitamin B-6 supplementation slightly affects memory performance but not mood in women of various ages", *J Nutr*, vol. 132, no. 6, pp. 1345-1356.

Buchsbaum, M. S., Siegel, B. V., Jr., Wu, J. C., Hazlett, E., Sicotte, N., Haier, R., Tanguay, P., Asarnow, R., Cadorette, T., Donoghue, D., & . 1992, "Brief report: attention performance in autism and regional brain metabolic rate assessed by positron emission tomography", *J Autism Dev Disord*, vol. 22, no. 1, pp. 115-125.

Burkinshaw, L., Jones, P. R., & Krupowicz, D. W. 1973, "Observer error in skinfold thickness measurements", *Hum Biol*, vol. 45, no. 2, pp. 273-279.

Butler, G. E., McKie, M., & Ratcliffe, S. G. 1990, "The cyclical nature of prepubertal growth", *Ann Hum Biol*, vol. 17, no. 3, pp. 177-198.

Cade, J. E., Barker, D. J., Margetts, B. M., & Morris, J. A. 1988, "Diet and inequalities in health in three English towns", *Br Med J*, vol. 296, no. 6633, pp. 1359-1362.

Campbell, L. R. & Cohen, M. 1990, "Management of attention deficit hyperactivity disorder (ADHD). A continuing dilemma for physicians and educators", *Clin Pediatr*, vol. 29, no. 3, pp. 191-193.

Caroline Walker Trust 1992, *Nutritional guidelines for school meals. Report of an expert Working Group.*, The Caroline Walker Trust, London.

Carroll J. 1963, "A model of school learning", *Teachers College Record* pp. 814-801.

Chandler, A. M., Walker, S. P., Connolly, K., & Grantham-McGregor, S. M. 1995, "School breakfast improves verbal fluency in undernourished Jamaican children", *J Nutr*, vol. 125, no. 4, pp. 894-900.

Chao E.S.M & Vanderkooy P.S 1989, "An overview of breakfast nutrition", *Journal of the Canadian Dietetic Association*, vol. 50, pp. 225-228.

Chaussain, J. L. 1973, "Glycemic response to 24 hour fast in normal children and children with ketotic hypoglycemia", *J Pediatr*, vol. 82, no. 3, pp. 438-443.

Chaussain, J. L., Georges, P., Olive, G., & Job, J. C. 1974, "Glycemic response to 24-hour fast in normal children and children with ketotic hypoglycemia: II. Hormonal and metabolic changes", *J Pediatr*, vol. 85, no. 6, pp. 776-781.

Chinn, S. & Rona, R. J. 1987, "Secular trends in weight, weight-for-height and triceps skinfold thickness in primary schoolchildren in England and Scotland from 1972 to 1980", *Ann Hum Biol*, vol. 14, no. 4, pp. 311-319.

Chinn, S. & Rona, R. J. 2001, "Prevalence and trends in overweight and obesity in three cross sectional studies of British Children, 1974-94", *BMJ*, vol. 322, no. 7277, pp. 24-26.

Cho, S., Dietrich, M., Brown, C. J., Clark, C. A., & Block, G. 2003, "The effect of breakfast type on total daily energy intake and body mass index: results from the Third National Health and Nutrition Examination Survey (NHANES III)", *J Am Coll Nutr*, vol. 22, no. 4, pp. 296-302.

Cohen, M. J., Hall, J., & Riccio, C. A. 1997, "Neuropsychological profiles of children diagnosed as specific language impaired with and without hyperlexia", *Arch Clin Neuropsychol*, vol. 12, no. 3, pp. 223-229.

Cole, T. J., Freeman, J. V., & Preece, M. A. 1995, "Body mass index reference curves for the UK, 1990", *Arch Dis Child*, vol. 73, no. 1, pp. 25-29.

COMA 1984, *Committee on Medical Aspects of Food Policy. Diet and Cardiovascular Disease. Report On Health and Social Subjects No 28* HMSO, London.

Conners, C. K. & Blouin, A. G. 1983, "Nutritional Effects on behaviour of Children", *J Psychiat Res*, vol. 17, no. 2, pp. 193-201.

Conners, C. K. 1969, "A teacher rating scale for use in drug studies with children", *Am J Psychiatry*, vol. 126, no. 6, pp. 884-888.

Cook J, Altman D.G, Moore, M. C., Topp S.G, Holland W.W, & Elliot, A. 1973, "A Survey of the nutritional status of schoolchildren - Relationship between nutrient intake and socio-ecnonmic factors", *Br J Prev Soc Med*, vol. 27, pp. 91-99.

Cook J, Altman D.G, Jacoby A, Holland W.W, & Elliot A 1975, "School meals and the nutrition of schoolchildren", *Br J Prev Soc Med*, vol. 29, pp. 182-189.

Cooper, D. M., Wasserman, D. H., Vranic, M., & Wasserman, K. 1986, "Glucose turnover in response to exercise during high- and low-FIO2 breathing in man", *Am J Physiol*, vol. 251, no. 2 Pt 1, p. E209-E214.

Cordain, L., Whicker, R. E., & Johnson, J. E. 1988, "Body composition determination in children using bioelectrical impedance", *Growth Dev Aging*, vol. 52, no. 1, pp. 37-40.

Costa, L. D. 1975, "The relation of visuospatial dysfunction to digit span performance in patients with cerebral lesions", *Cortex*, vol. 11, no. 1, pp. 31-36.

Cox, D. J. & Gonder-Frederick, L. 1992, "Major developments in behavioral diabetes research", *J Consult Clin Psychol.*, vol. 60, no. 4, pp. 628-638.

Craft S, Murphy G, & Wemstorm J 1994, "Glucose Effects on complex memory and nonmemory tasks: the influence of age, sex, and glucoregulaory response", *Psychobiology*, vol. 1994, no. 22, pp. 95-105.

Craft, S., Zallen, G., & Baker, L. D. 1992, "Glucose and memory in mild senile dementia of the Alzheimer type", *J Clin Exp Neuropsychol*, vol. 14, no. 2, pp. 253-267.

Craft, S., Dagogo-Jack, S. E., Wiethop, B. V., Murphy, C., Nevins, R. T., Fleischman, S., Rice, V., Newcomer, J. W., & Cryer, P. E. 1993, "Effects of hyperglycemia on memory and hormone levels in dementia of the Alzheimer type: a longitudinal study", *Behav Neurosci*, vol. 107, no. 6, pp. 926-940.

Crawley, H. F. 1993, "The energy, nutrient and food intakes of teenagers aged 16-17 years in Britain. 1. Energy, macronutrients and non-starch polysaccharides", *Br J Nutr*, vol. 70, no. 1, pp. 15-26.

Cresswell, J., Busby, A., Young, H., & Inglis, V. 1983, "Dietary patterns of third-year secondary schoolgirls in Glasgow", *Hum Nutr Appl Nutr*, vol. 37, no. 4, pp. 301-306.

Cromer B.A, Tarnowski K.J, Stein A.M, & Thornton D.J 1990, "The School Breakfast Program and Cognition in Adolescents", *Developmental and Behavioral Pediatrics*, vol. 11, no. 6, pp. 295-300.

Curry C & Todd J 1992, *Health Behaviours of Scottish Schoolchildren. Report 1: National and regional patterns Research Unit in Health and Behavioural Change,* Health Education Board for Scotland, Edinburgh.

Danford, L. C., Schoeller, D. A., & Kushner, R. F. 1992, "Comparison of two bioelectrical impedance analysis models for total body water measurement in children", *Ann Hum Biol*, vol. 19, no. 6, pp. 603-607.

Davies, P. & Maloney, A. J. 1976, "Selective loss of central cholinergic neurons in Alzheimer's disease", *Lancet*, vol. 2, no. 8000, p. 1403.

Davies, P. S., Preece, M. A., Hicks, C. J., & Halliday, D. 1988, "The prediction of total body water using bioelectrical impedance in children and adolescents", *Ann Hum Biol*, vol. 15, no. 3, pp. 237-240.

Deary, I. J. & Caryl, P. G. 1997, "Neuroscience and human intelligence differences", *Trends Neurosci*, vol. 20, no. 8, pp. 365-371.

Deary, I. J. 1999, "A taxonomy of medically unexplained symptoms", *J Psychosom Res*, vol. 47, no. 1, pp. 51-59.

DEFRA 2002, *Expenditure and Food Survey: Family Food in 2001/2* http://statistics.defra.gov.uk.

Deijen, J. B., Heemstra, M. L., & Orlebeke, J. F. 1989, "Dietary effects on mood and performance", *J Psychiatr Res*, vol. 23, no. 3-4, pp. 275-283.

Deinhard A.S, List A, Lindgren B, Hunt J.V, & Chang P.N 996, "Cognitive effects of iron deficiency anaemia", *J Paed*, vol. 108, pp. 681-689.

Department Of Health and Social Security no 120 1969, *Recommended Intakes of Nutrients for the United Kingdom. Reports on public health and medical subjects.*, HMSO, London.

Department of Health 1989, "National Food Survey," HMSO, London.

Department of Health 1989, *Department of Health. The Diets Of British Schoolchildren. Report on Health and Social Subjects no 36*, HMSO, London.

Department of Health 1991, *Department of Health Dietary Reference Values for food energy and nutrients for the United Kingdom Report on Health and Social Subject no.41 London: HMSO.*

Department of Health 1991, *Dietary Reference Values for food energy and nutrients for the United Kingdom. Report on Health and Social Subjects no.41. London:HMSO.*

Department of Health 1999, *The White Paper: Improving the Health of the Nation.*

Deurenberg, P., Weststrate, J. A., & van der, K. K. 1989, "Body composition changes assessed by bioelectrical impedance measurements", *Am J Clin Nutr*, vol. 49, no. 3, pp. 401-403.

Deurenberg, P., Kusters, C. S., & Smit, H. E. 1990, "Assessment of body composition by bioelectrical impedance in children and young adults is strongly age-dependent", *Eur J Clin Nutr*, vol. 44, no. 4, pp. 261-268.

Deurenberg, P., van der, K. K., Leenen, R., Weststrate, J. A., & Seidell, J. C. 1991, "Sex and age specific prediction formulas for estimating body composition from bioelectrical impedance: a cross-validation study", *Int J Obes*, vol. 15, no. 1, pp. 17-25.

Devaney B. & Stuart E. 1998, *Eating Breakfast:Effects of the School Breakfast Program* Contract No-53-3198-7-006.

Dickie, N. H. & Bender, A. E. 1982, "Breakfast and performance in school children", *Br J Nutr*, vol. 48, no. 3, pp. 483-496.

Dickie, N. H. & Bender, A. E. 1982, "Breakfast and performance", *Hum Nutr Appl Nutr*, vol. 36, no. 1, pp. 46-56.

Dietz, W. H. & Robinson, T. N. 1998, "Use of the body mass index (BMI) as a measure of overweight in children and adolescents", *J Pediatr*, vol. 132, no. 2, pp. 191-193.

Dollinger, S. J., Goh, D. S., & Cody, J. J. 1984, "A note on the congruence of the WISC-R and the cognitive development scales of the personality inventory for children", *J Consult Clin Psychol*, vol. 52, no. 2, pp. 315-316.

Domel, S. B., Thompson, W. O., Baranowski, T., & Smith, A. F. 1994, "How children remember what they have eaten", *J Am Diet Assoc*, vol. 94, no. 11, pp. 1267-1272.

Donohoe, R. T. & Benton, D. 1999, "Cognitive functioning is susceptible to the level of blood glucose", *Psychopharmacology*, vol. 145, no. 4, pp. 378-385.

Dowler, E. & Calvert, C. 1995, "Looking for 'fresh' food: diet and lone parents", *Proc Nutr Soc*, vol. 54, no. 3, pp. 759-769.

Doyle, W., Jenkins, S., Crawford, M. A., & Puvandendran, K. 1994, "Nutritional status of schoolchildren in an inner city area", *Arch Dis Child*, vol. 70, no. 5, pp. 376-381.

Durkin, T. P., Messier, C., de Boer, P., & Westerink, B. H. 1992, "Raised glucose levels enhance scopolamine-induced acetylcholine overflow from the hippocampus: an in vivo microdialysis study in the rat", *Behav Brain Res*, vol. 49, no. 2, pp. 181-188.

Durnin, J. V. & Rahaman, M. M. 1967, "The assessment of the amount of fat in the human body from measurements of skinfold thickness", *Br J Nutr*, vol. 21, no. 3, pp. 681-689.

Durnin, J. V., Lonergan, M. E., Good, J., & Ewan, A. 1974, "A cross-sectional nutritional and anthropometric study, with an interval of 7 years, on 611 young adolescent schoolchildren", *Br J Nutr*, vol. 32, no. 1, pp. 169-179.

Dwyer J.T, Hewes L.V, Mithchell M.S, Nicklas T.A, Montgomery D.H, Lytle, L., Snyder M.P, Zive M.W, Bachman K.J, Rice R, & Parcel G.S 1996, "Improving School Breakfasts: Effects of the CATCH Eat Smart Program on the Nutrient Content of school Breakfasts", *Preventative Medicine*, vol. 25, pp. 413-422.

Dye, L., Lluch, A., & Blundell, J. E. 2000, "Macronutrients and mental performance", *Nutrition*, vol. 16, no. 10, pp. 1021-1034.

Edelbrock C & Achenbach T.M 1984, "The Teacher Version of the Child Behavior Profile: I. Boys Aged 6-11.", *J Cons Clin Psyc*, vol. 52, pp. 207-217.

Edington, J. 1999, "Problems of nutritional assessment in the community", *Proc Nutr Soc*, vol. 58, no. 1, pp. 47-51.

Elias, P. K., Elias, M. F., D'Agostino, R. B., Cupples, L. A., Wilson, P. W., Silbershatz, H., & Wolf, P. A. 1997, "NIDDM and blood pressure as risk factors for poor cognitive performance. The Framingham Study", *Diabetes Care*, vol. 20, no. 9, pp. 1388-1395.

Ewing, F. M., Deary, I. J., McCrimmon, R. J., Strachan, M. W., & Frier, B. M. 1998, "Effect of acute hypoglycemia on visual information processing in adults with type 1 diabetes mellitus", *Physiol Behav*, vol. 64, no. 5, pp. 653-660.

Fearon, K. C., Richardson, R. A., Hannan, J., Cowan, S., Watson, W., Shenkin, A., & Garden, O. J. 1992, "Bioelectrical impedance analysis in the measurement of the body composition of surgical patients", *Br J Surg*, vol. 79, no. 5, pp. 421-423.

Fernstorm 1994, "The effect of dietary macronutrients on brain serotonin formation.", *Appetite and Body Weigh Regulation*, vol. 9, no. 18, pp. 51-62.

Fernstrom, J. D. & Wurtman, R. J. 1971, "Brain serotonin content: increase following ingestion of carbohydrate diet", *Science*, vol. 174, no. 13, pp. 1023-1025.

Fischer, K., Colombani, P. C., Langhans, W., & Wenk, C. 2001, "Cognitive performance and its relationship with postprandial metabolic changes after ingestion of different macronutrients in the morning", *Br J Nutr*, vol. 85, no. 3, pp. 393-405.

Foster, J. K., Lidder, P. G., & Sunram, S. I. 1998, "Glucose and memory: fractionation of enhancement effects?", *Psychopharmacology* , vol. 137, no. 3, pp. 259-270.

Frape, D. L., Williams, N. R., Rajput-Williams, J., Maitland, B. W., Scriven, A. J., Palmer, C. R., & Fletcher, R. J. 1998, "Effect of breakfast fat content on glucose tolerance and risk factors of atherosclerosis and thrombosis", *Br J Nutr*, vol. 80, no. 4, pp. 323-331.

Fray, A. E., Forsyth, R. J., Boutelle, M. G., & Fillenz, M. 1996, "The mechanisms controlling physiologically stimulated changes in rat brain glucose and lactate: a microdialysis study", *J Physiol*, vol. 496 (Pt 1), pp. 49-57.

Freedman, D. S., Khan, L. K., Serdula, M. K., Srinivasan, S. R., & Berenson, G. S. 2000, "Secular trends in height among children during 2 decades: The Bogalusa Heart Study", *Arch Pediatr Adolesc Med*, vol. 154, no. 2, pp. 155-161.

Freeman, J. V., Cole, T. J., Chinn, S., Jones, P. R., White, E. M., & Preece, M. A. 1995, "Cross sectional stature and weight reference curves for the UK, 1990", *Arch Dis Child*, vol. 73, no. 1, pp. 17-24.

Fuller, N. J., Jebb, S. A., Laskey, M. A., Coward, W. A., & Elia, M. 1992, "Four-component model for the assessment of body composition in humans: comparison with alternative methods, and evaluation of the density and hydration of fat-free mass", *Clin Sci*, vol. 82, no. 6, pp. 687-693.

Galey, D., Durkin, T., Sifakis, G., Kempf, E., & Jaffard, R. 1985, "Facilitation of spontaneous and learned spatial behaviours following 6-hydroxydopamine lesions of the lateral septum: a cholinergic hypothesis", *Brain Res*, vol. 340, no. 1, pp. 171-174.

Gallagher, M., Walker, K. Z., & O'Dea, K. 1998, "The influence of a breakfast meal on the assessment of body composition using bioelectrical impedance", *Eur J Clin Nutr*, vol. 52, no. 2, pp. 94-97.

Gardner and Merchant 1998, *What are today's children eating?*

Gardner, R., Jr., Oliver-Munoz, S., Fisher, L., & Empting, L. 1981, "Mattis Dementia Rating Scale: internal reliability study using a diffusely impaired population", *J Clin Neuropsychol.*, vol. 3, no. 3, pp. 271-275.

Garrow J.S 1983, "Indices of adposity", *Nutr Abstracts and Reviews*, vol. 53, pp. 697-708.

Gartner, A., Maire, B., Delpeuch, F., Sarda, P., Dupuy, R. P., & Rieu, D. 1992, "Importance of electrode position in bioelectrical impedance analysis", *Am J Clin Nutr*, vol. 56, no. 6, pp. 1067-1068.

Gibson S & Ashwell M 2004, "How can we identify schoolgirls at risk iron status and what dietary advice should we be giving?", *(in press)*.

Gibson, S. 2003, "Micronutrient intakes, micronutrient status and lipid profiles among young people consuming different amounts of breakfast cereals: further analysis of data from the National Diet and Nutrition Survey of Young People aged 4 to 18 years", *Public Health Nutr*, vol. 6, no. 8, pp. 815-820.

Gibson, S. A. & O'Sullivan, K. R. 1995, "Breakfast cereal consumption patterns and nutrient intakes of British schoolchildren", *J R Soc Health*, vol. 115, no. 6, pp. 366-370.

Gibson, S. A. 1999, "Iron intake and iron status of preschool children: associations with breakfast cereals, vitamin C and meat", *Public Health Nutr*, vol. 2, no. 4, pp. 521-528.

Glow, R. A., Glow, P. H., & Rump, E. E. 1982, "The stability of child behavior disorders: a one year test-retest study of Adelaide versions of the Conners Teacher and Parent Rating Scales", *J Abnorm Child Psychol*, vol. 10, no. 1, pp. 33-60.

Gold, A. E., MacLeod, K. M., & Frier, B. M. 1994, "Frequency of severe hypoglycemia in patients with type I diabetes with impaired awareness of hypoglycemia", *Diabetes Care*, vol. 17, no. 7, pp. 697-703.

Gold, A. E., MacLeod, K. M., Deary, I. J., & Frier, B. M. 1995, "Hypoglycemia-induced cognitive dysfunction in diabetes mellitus: effect of hypoglycemia unawareness", *Physiol Behav*, vol. 58, no. 3, pp. 501-511.

Gold, P. E. 1986, "Glucose modulation of memory storage processing", *Behav Neural Biol*, vol. 45, no. 3, pp. 342-349.

Gold, P. E., Vogt, J., & Hall, J. L. 1986, "Glucose effects on memory: behavioral and pharmacological characteristics", *Behav Neural Biol*, vol. 46, no. 2, pp. 145-155.

Gold, P. E. 1995, "Role of glucose in regulating the brain and cognition", *Am J Clin Nutr*, vol. 61, no. 4 Suppl, pp. 987S-995S.

Goldberg, G. R., Black A.E., Jebb S.A., Cole T.J., Murgatroyd P.R., Coward A.E., & Prentice A.M 1991, "Critical Evaluation of energy intake data using the fundamental principles of energy physiology:1 Derivation of cut-off limits to identify under-reporting", *Eur J Clin Nutr*, vol. 45, pp. 569-581.

Golding J, Haslum J., & Morris A 1984, "The Eating Habits of ten-year-olds", *Health Visitor*, vol. 57, pp. 178-179.

Goyen, J. D. & Lyle, J. G. 1973, "Short-term memory and visual discrimination in retarded readers", *Percept Mot Skills*, vol. 36, no. 2, pp. 403-408.

Grantham-McGregor, S. M., Chang, S., & Walker, S. P. 1998, "Evaluation of school feeding programs: some Jamaican examples", *Am J Clin Nutr*, vol. 67, no. 4, pp. 785S-789S.

Green, M. W., Elliman, N. A., & Rogers, P. J. 1997, "The effects of food deprivation and incentive motivation on blood glucose levels and cognitive function", *Psychopharmacology*, vol. 134, no. 1, pp. 88-94.

Greer M.S 1990, "Impact of breakfast on nutrient intake, low-income.", *M.S thesis* pp. 1-74.

Gregory J, Collins D, Dvaies P, Hughes J, & Clarke P 1995, *National Diet and Nutrition Survey: children aged 1.5 to 4.5 years. Vol.1 Report of the diet and nutrition survey. Office of the Population Censuses and Surveys. Social Survey Division* HMSO, London.

Gregory J & Lowe S 2004, *National Diet and Nutrition Survey; young people aged 4 to 18 years. Vol, 1. Report of the diet and nutrition survey 2000, Office of the Population Censuses and Surveys, Social Survey Division* HMSO, London.

Gregory, J. W., Greene, S. A., Scrimgeour, C. M., & Rennie, M. J. 1991, "Body water measurement in growth disorders: a comparison of bioelectrical impedance and skinfold thickness techniques with isotope dilution", *Arch Dis Child*, vol. 66, no. 2, pp. 220-222.

Haier, R. J., Siegel, B. V., Jr., MacLachlan, A., Soderling, E., Lottenberg, S., & Buchsbaum, M. S. 1992, "Regional glucose metabolic changes after learning a complex visuospatial/motor task: a positron emission tomographic study", *Brain Res*, vol. 570, no. 1-2, pp. 134-143.

Hall, J. L. & Gold, P. E. 1986, "The effects of training, epinephrine, and glucose injections on plasma glucose levels in rats", *Behav Neural Biol.*, vol. 46, no. 2, pp. 156-167.

Hall, J. L., Gonder-Frederick, L. A., Chewning, W. W., Silveira, J., & Gold, P. E. 1989, "Glucose enhancement of performance on memory tests in young and aged humans", *Neuropsychologia*, vol. 27, no. 9, pp. 1129-1138.

Hall, J. L. & Gold, P. E. 1992, "Plasma glucose levels predict the disrupting effects of adrenoceptor antagonists on enhancement of memory storage", *Eur J Pharmacol*, vol. 221, no. 2-3, pp. 365-370.

Harries, A. D., Jones, L. A., Heatley, R. V., & Rhodes, J. 1983, "Assessment of nutritional status by anthropometry: a comparison of different standards of reference", *Hum Nutr Clin Nutr*, vol. 37, no. 3, pp. 227-231.

Harrop A & Palmer G 2002, *Improving Breakfast Clubs: Lessons From The Best*, New Policy Institute.

Holcomb, W. R., Hardesty, R. A., Adams, N. A., & Ponder, H. M. 1987, "WISC-R types of learning disabilities: a profile analysis with cross-validation", *J Learn Disabil*, vol. 20, no. 6, pp. 369-373.

Holt S.H.A, Delargy H.J, Lawton C.L, & Blundell J.E 1999, *The Effects of high-carbohydrate vs high-fat breakfast on feelings of fullness and alertness, and subsequent food intake* 50.

Horn, J. L. & Cattell, R. B. 1966, "Refinement and test of the theory of fluid and crystallized general intelligences", *J Educ Psychol*, vol. 57, no. 5, pp. 253-270.

Houtkooper, L. B., Going, S. B., Lohman, T. G., Roche, A. F., & Van Loan, M. 1992, "Bioelectrical impedance estimation of fat-free body mass in children and youth: a cross-validation study", *J Appl Physiol*, vol. 72, no. 1, pp. 366-373.

Houtkooper, L. B., Lohman, T. G., Going, S. B., & Howell, W. H. 1996, "Why bioelectrical impedance analysis should be used for estimating adiposity", *Am J Clin Nutr*, vol. 64, no. 3 Suppl, pp. 436S-448S.

Hughes, J. M., Li, L., Chinn, S., & Rona, R. J. 1997, "Trends in growth in England and Scotland, 1972 to 1994", *Arch Dis Child*, vol. 76, no. 3, pp. 182-189.

Iwata, K., Satou, Y., Iwata, F., Hara, M., Fuchigami, S., Kin, H., Fuchigami, T., Okada, T., Harada, K., Ohkuni, M., & . 1993, "Assessment of body composition measured by bioelectrical impedance in children", *Acta Paediatr Jpn*, vol. 35, no. 5, pp. 369-372.

Jacoby, E. R., Cueto, S., & Pollitt, E. 1998, "When science and politics listen to each other: good prospects from a new school breakfast program in Peru", *Am J Clin Nutr*, vol. 67, no. 4, pp. 795S-797S.

Jarrard, L. E. & Lewis, T. C. 1967, "Effects of hippocampal ablation and intertrial interval on acquisition and extinction in a complex maze", *Am J Psychol*, vol. 80, no. 1, pp. 66-72.

Jenkins, D. J., Wolever, T. M., Taylor, R. H., Barker, H., Fielden, H., Baldwin, J. M., Bowling, A. C., Newman, H. C., Jenkins, A. L., & Goff, D. V. 1981, "Glycemic index of foods: a physiological basis for carbohydrate exchange", *Am J Clin Nutr*, vol. 34, no. 3, pp. 362-366.

Johnson, E. G. & Lyle J.G 1972, "Analysis of WISC Coding: 1. Figure Reversability", *Perceptual and Motor Skills*, vol. 34, pp. 195-198.

Johnson, E. G. & Lyle J.G 1975, "Analysis Of Wisc Coding. 2.memory and verbal mediation", *Percept Mot Skills*, vol. 37, pp. 695-662.

Kafatos A.G, Linarhakis M, Bertsias G.K, Mammas I.A, Fletcher R.J, & Bervanaki F 2003, *Consumption of ready-to-eat cereals in relations to health and diet indicators among adolescents in Crete, Greece.*

Kandel, E. R. & Squire, L. R. 2000, "Neuroscience: breaking down scientific barriers to the study of brain and mind", *Science*, vol. 290, no. 5494, pp. 1113-1120.

Kennedy, E. & Davis, C. 1998, "US Department of Agriculture School Breakfast Program", *Am J Clin Nutr*, vol. 67, no. 4, pp. 798S-803S.

Kirk, T. R., Burkill, S., & Cursiter, M. 1997, "Dietary fat reduction achieved by increasing consumption of a starchy food--an intervention study", *Eur J Clin Nutr*, vol. 51, no. 7, pp. 455-461.

Kleinman, R. E., Murphy, J. M., Little, M., Pagano, M., Wehler, C. A., Regal, K., & Jellinek, M. S. 1998, "Hunger in children in the United States: potential behavioral and emotional correlates", *Pediatrics*, vol. 101, no. 1, p. E3.

Knuiman, J. T., Rasanen, L., Ahola, M., West, C. E., & van der, S. L. 1987, "The relative validity of reports of food intake of Dutch and Finnish boys aged 8 and 9 years", *J Am Diet Assoc*, vol. 87, no. 3, pp. 303-307.

Koehler, K. M., Romero, L. J., Stauber, P. M., Pareo-Tubbeh, S. L., Liang, H. C., Baumgartner, R. N., Garry, P. J., Allen, R. H., & Stabler, S. P. 1996, "Vitamin supplementation and other variables affecting serum homocysteine and methylmalonic acid concentrations in elderly men and women", *J Am Coll Nutr*, vol. 15, no. 4, pp. 364-376.

Kopelman, M. D. 1986, "The cholinergic neurotransmitter system in human memory and dementia: a review", *J Exp Psychol*, vol. 38, no. 4, pp. 535-573.

Korol, D. L. & Gold, P. E. 1998, "Glucose, memory, and aging", *Am J Clin Nutr*, vol. 67, no. 4, pp. 764S-771S.

Kuntscherova, J. 1972, "Effect of short-term starvation and choline on the acetylcholine content of organs of albino rats", *Physiol Biochem*, vol. 21, no. 6, pp. 655-660.

Kushner, R. F. & Schoeller, D. A. 1986, "Estimation of total body water by bioelectrical impedance analysis", *Am J Clin Nutr* , vol. 44, no. 3, pp. 417-424.

Kushner, R. F., Kunigk, A., Alspaugh, M., Andronis, P. T., Leitch, C. A., & Schoeller, D. A. 1990, "Validation of bioelectrical-impedance analysis as a measurement of change in body composition in obesity", *Am J Clin Nutr*, vol. 52, no. 2, pp. 219-223.

Kushner, R. F. 1992, "Bioelectrical impedance analysis: a review of principles and applications", *J Am Coll Nutr*, vol. 11, no. 2, pp. 199-209.

Lauer, R. M., Lee, J., & Clarke, W. R. 1988, "Factors affecting the relationship between childhood and adult cholesterol levels: the Muscatine Study", *Pediatrics*, vol. 82, no. 3, pp. 309-318.

Lean, M. E., Anderson, A. S., & Coubrough, H. A. 1988, "Towards NACNE: improving eating habits in a Scottish health board", *Eur J Clin Nutr*, vol. 42, no. 2, pp. 177-184.

Lee, M. K., Graham, S. N., & Gold, P. E. 1988, "Memory enhancement with posttraining intraventricular glucose injections in rats", *Behav Neurosci*, vol. 102, no. 4, pp. 591-595.

Liang, K. C. & McGaugh, J. L. 1983, "Lesions of the stria terminalis attenuate the amnestic effect of amygdaloid stimulation on avoidance responses", *Brain Res*, vol. 274, no. 2, pp. 309-318.

Lieberman, H. R. & Wurtman, R. J. 1986, "Foods and food constituents that affect the brain and human behavior", *Food Technol*, vol. 40, no. 1, pp. 139-141.

Lindeman A.K & Clancy K.L 1990, "Assessment of Breakfast habits and social/emotional Behavior of Elementary Schoolchildren", *J Nutr Educ Vol*, vol. 22, no. 5, pp. 226-231.

Livingstone M.B.E 2004, "Children's food and snacking", *Carbohydrate*, vol. 2, pp. 3-4.

Livingstone, M. B., Prentice, A. M., Strain, J. J., Coward, W. A., Black, A. E., Barker, M. E., McKenna, P. G., & Whitehead, R. G. 1990, "Accuracy of weighed dietary records in studies of diet and health", *BMJ*, vol. 300, no. 6726, pp. 708-712.

Livingstone, M. B., Prentice, A. M., Coward, W. A., Strain, J. J., Black, A. E., Davies, P. S., Stewart, C. M., McKenna, P. G., & Whitehead, R. G. 1992, "Validation of estimates of energy intake by weighed dietary record and diet history in children and adolescents", *Am J Clin Nutr*, vol. 56, no. 1, pp. 29-35.

Livingstone, M. B. 1995, "Assessment of food intakes: are we measuring what people eat?", *Br J Biomed Sci*, vol. 52, no. 1, pp. 58-67.

Livingstone, M. B. & Robson, P. J. 2000, "Measurement of dietary intake in children", *Proc Nutr Soc*, vol. 59, no. 2, pp. 279-293.

Lloyd, H. M., Green, M. W., & Rogers, P. J. 1994, "Mood and cognitive performance effects of isocaloric lunches differing in fat and carbohydrate content", *Physiol Behav*, vol. 56, no. 1, pp. 51-57.

Lloyd, H. M., Rogers, P. J., Hedderley, D. I., & Walker, A. F. 1996, "Acute effects on mood and cognitive performance of breakfasts differing in fat and carbohydrate content", *Appetite*, vol. 27, no. 2, pp. 151-164.

Lohman, T. G. 1981, "Skinfolds and body density and their relation to body fatness: a review", *Hum Biol*, vol. 53, no. 2, pp. 181-225.

Lopez, I., de, A., I, Perales, C. G., Heresi, E., Castillo, M., & Colombo, M. 1993, "Breakfast omission and cognitive performance of normal, wasted and stunted schoolchildren", *Eur J Clin Nutr*, vol. 47, no. 8, pp. 533-542.

Lorenzo, A., Barra, P. F., Sasso, G. F., Battistini, N. C., & Deurenberg, P. 1991, "Body impedance measurements during dialysis", *Eur J Clin Nutr*, vol. 45, no. 6, pp. 321-325.

Lufi, D. & Cohen, A. 1985, "Attentional deficit disorder and short-term visual memory", *J Clin Psychol*, vol. 41, no. 2, pp. 265-267.

Lukaski, H. C. 1987, "Methods for the assessment of human body composition: traditional and new", *Am J Clin Nutr*, vol. 46, no. 4, pp. 537-556.

Lussier-Cacan, S., Xhignesse, M., Piolot, A., Selhub, J., Davignon, J., & Genest, J., Jr. 1996, "Plasma total homocysteine in healthy subjects: sex-specific relation with biological traits", *Am J Clin Nutr*, vol. 64, no. 4, pp. 587-593.

Lyle J.G & Johnson, E. G. 1974, "Analysis of Wisc Coding: 5 Prediction of coding performance", *Percept Mot Skills* pp. 111-114.

Lyle, J. G. & Johnson, E. G. 1973, "Analysis of WISC coding: 3 Writing and copying speed, and motivation", *Percept Mot Skills*, vol. 36, no. 1, pp. 211-214.

Macdiarmid, J. I., Vail, A., Cade, J. E., & Blundell, J. E. 1998, "The sugar-fat relationship revisited: differences in consumption between men and women of varying BMI", *Int J Obes Relat Metab Disord.*, vol. 22, no. 11, pp. 1053-1061.

MacMahon, S. 1992, "Lowering cholesterol: effects on trauma death, cancer death and total mortality", *Aust N Z J Med*, vol. 22, no. 5 Suppl, pp. 580-582.

Magarey A, Nichols, J., & Boulton J 1987, "Food Intake at age 8. 3. Distribution and food density by meal.", *Australian Paediatric Journal*, vol. 23, pp. 217-221.

Magarey A. & Boulton J. 1995, "The Adelaide nutrition study.4. Meal habits and distribution of energy and nutrients throughout the day at ages 11,13, 15", *Australian Journal of Nutrition and Dietetics*, vol. 52, pp. 132-138.

Magarey, A. & Boulton, T. J. 1987, "Food intake during childhood: percentiles of food energy, macronutrient and selected micronutrients from infancy to eight years of age", *Med J Aust*, vol. 147, no. 3, pp. 124-127.

Magarey, A. & Boulton, J. 1987, "Energy and nutrient intake at age 6 and its relationship to body size and fatness", *Aust Paediatr J*, vol. 23, no. 1, pp. 41-46.

Manning C.A, Parsons M.W, & Gold P.E 1992, "Anterograde and Retrograde Enhancement of 24h-Memory by Glucose in Elderly Humans", *Brain Res*, vol. 58, pp. 125-130.

Marr, J. W. 1971, "Individual dietary surveys: purposes and methods", *World Rev Nutr Diet*, vol. 13, pp. 105-164.

Martin, R. B. 2003, "Fatigue damage, remodeling, and the minimization of skeletal weight", *J Theor Biol*, vol. 220, no. 2, pp. 271-276.

McCaddon, A., Davies, G., Hudson, P., Tandy, S., & Cattell, H. 1998, "Total serum homocysteine in senile dementia of Alzheimer type", *Int J Geriatr Psychiatry*, vol. 13, no. 4, pp. 235-239.

McDonald, R. J. & White, N. M. 1993, "A triple dissociation of memory systems: hippocampus, amygdala, and dorsal striatum", *Behav Neurosci*, vol. 107, no. 1, pp. 3-22.

McLeod K.M, Gold A.E., & Ebmeier K.P 1996, "The Effects of acute hypoglycaemia on relative cerebral blood flow distribution in patients with

type I diabetes and impaired hypogycaemic awareness.", *Metabolism*, vol. 45.

McNulty, H., Eaton-Evans, J., Cran, G., Woulahan, G., Boreham, C., Savage, J. M., Fletcher, R., & Strain, J. J. 1996, "Nutrient intakes and impact of fortified breakfast cereals in schoolchildren", *Arch Dis Child*, vol. 75, no. 6, pp. 474-481.

Mensink, R. P. & Katan, M. B. 1990, "Effect of dietary trans fatty acids on high-density and low-density lipoprotein cholesterol levels in healthy subjects", *N Engl J Med*, vol. 323, no. 7, pp. 439-445.

Messier, C. & White, N. M. 1987, "Memory improvement by glucose, fructose, and two glucose analogs: a possible effect on peripheral glucose transport", *Behav Neural Biol.*, vol. 48, no. 1, pp. 104-127.

Messier, C., Durkin, T., Mrabet, O., & Destrade, C. 1990, "Memory-improving action of glucose: indirect evidence for a facilitation of hippocampal acetylcholine synthesis", *Behav Brain Res*, vol. 39, no. 2, pp. 135-143.

Meyers, A. F., Sampson, A. E., Weitzman, M., Rogers, B. L., & Kayne, H. 1989, "School Breakfast Program and school performance", *Am J Dis Child*, vol. 143, no. 10, pp. 1234-1239.

Ministry of Education 1950, "Nutriton recommendations for school meals. Government Circular no 290," HMSO, London.

Mohs, R. C., Davis, B. M., Greenwald, B. S., Mathe, A. A., Johns, C. A., Horvath, T. B., & Davis, K. L. 1985, "Clinical studies of the cholinergic deficit in Alzheimer's disease. II. Psychopharmacologic studies", *J Am Geriatr Soc*, vol. 33, no. 11, pp. 749-757.

Monk, T. H., Fookson, J. E., Moline, M. L., & Pollak, C. P. 1985, "Diurnal variation in mood and performance in a time-isolated environment", *Chronobiol Int*, vol. 2, no. 3, pp. 185-193.

Morgan, K. J., Zabik, M. E., & Leveille, G. A. 1981, "The role of breakfast in nutrient intake of 5- to 12-year-old children", *Am J Clin Nutr*, vol. 34, no. 7, pp. 1418-1427.

Morgan, K. J., Zabik, M. E., & Stampley, G. L. 1986, "The role of breakfast in diet adequacy of the U.S. adult population", *J Am Coll Nutr*, vol. 5, no. 6, pp. 551-563.

Morgan, R. W., Jain, M., Miller, A. B., Choi, N. W., Matthews, V., Munan, L., Burch, J. D., Feather, J., Howe, G. R., & Kelly, A. 1978, "A comparison of dietary methods in epidemiologic studies", *Am J Epidemiol*, vol. 107, no. 6, pp. 488-498.

Murphy J.M, Wehler C.A, Pagano M.E, Little M, Kleinman, R. E., & Jellinek M.S 98 A.D., "Relationship Between Hunger and Psychosocial Functioning in Low-Income Amercian Children", *J Am Acad Child Adolsc Psychiatry*, vol. 37, no. 2, pp. 163-170.

National Advisory Commitee on Nutrition Education 1983, *A Discussion Paper on proposals for nutritional guidelines for health* , Health Education Council, London.

Nelson, M., Naismith, D. J., Burley, V., Gatenby, S., & Geddes, N. 1990, "Nutrient intakes, vitamin-mineral supplementation, and intelligence in British schoolchildren", *Br J Nutr*, vol. 64, no. 1, pp. 13-22.

Nelson, M. 2000, "Childhood nutrition and poverty", *Proc Nutr Soc*, vol. 59, no. 2, pp. 307-315.

Newsholme, E. A., Arch, J. R., Brooks, B., & Surholt, B. 1983, "The role of substrate cycles in metabolic regulation", *Biochem Soc Trans*, vol. 11, no. 1, pp. 52-56.

Nicklas, T. A., Webber, L. S., Koschak, M., & Berenson, G. S. 1992, "Nutrient adequacy of low fat intakes for children: the Bogalusa Heart Study", *Pediatrics*, vol. 89, no. 2, pp. 221-228.

Nicklas, T. A., Bao, W., Webber, L. S., & Berenson, G. S. 1993, "Breakfast consumption affects adequacy of total daily intake in children", *J Am Diet Assoc*, vol. 93, no. 8, pp. 886-891.

Nicklas, T. A., O'Neil, C. E., & Berenson, G. S. 1998, "Nutrient contribution of breakfast, secular trends, and the role of ready-to-eat cereals: a review of data from the Bogalusa Heart Study", *Am J Clin Nutr*, vol. 67, no. 4, pp. 757S-763S.

Nicklas, T. A., Reger C, Myers L, & O'Neil C 2000, "Breakfast Consumption With and Without Vitamin Mineral Supplement Use favourably impacts Daily Nutrient Intake of Ninth-Grade students", *Journal of Adolescent Health*, vol. 27, pp. 314-321.

Norgan, N. G. 1990, "Body mass index and body energy stores in developing countries", *Eur J Clin Nutr*, vol. 44 Suppl 1, pp. 79-84.

Olson, R. E. 2002, "The role of dietary and plasma lipids in childhood atherogenesis", *Pediatr Pathol Mol Med*, vol. 21, no. 2, pp. 137-152.

Ortega R.M, Requejo A.M, Redondo R, Lopez-Sobaler A.M, Andres P, Ortega A, Quintas E, & Izquierdo M 1996, "Breakfast Habits Of Different Groups Of Spanish Schoolchildren", *Journal of Human Nutrition and Dietetics*, vol. 9, pp. 33-41.

Owen S & Benton D 2003, "The Impact of Raising Blood Glucose on Reaction times", *Biological Psychology*, vol. 30, pp. 106-113.

Paige, D. M., Cordano, A., & Huang, S. S. 1976, "Nutritional supplementation of disadvantaged elementary-school children", *Pediatrics*, vol. 58, no. 5, pp. 697-703.

Parker, P. Y. & Benton, D. 1995, "Blood glucose levels selectively influence memory for word lists dichotically presented to the right ear", *Neuropsychologia*, vol. 33, no. 7, pp. 843-854.

Parsons, M. W. & Gold, P. E. 1992, "Glucose enhancement of memory in elderly humans: an inverted-U dose-response curve", *Neurobiol Aging*, vol. 13, no. 3, pp. 401-404.

Payne J.A & Belton N.R 1993, "Eating Habits, nutrient intake and growth in pre-school children", *J Hum Nutr Diet*, vol. 5, pp. 299-304.

Pivonka, E. E. & Grunewald, K. K. 1990, "Aspartame- or sugar-sweetened beverages: effects on mood in young women", *J Am Diet Assoc*, vol. 90, no. 2, pp. 250-254.

Pollitt, E., Leibel, R. L., & Greenfield, D. 1981, "Brief fasting, stress, and cognition in children", *Am J Clin Nutr*, vol. 34, no. 8, pp. 1526-1533.

Pollitt, E., Lewis, N. L., Garza, C., & Shulman, R. J. 1982, "Fasting and cognitive function", *J Psychiatr Res*, vol. 17, no. 2, pp. 169-174.

Pollitt, E. & Lorimor, R. 1983, "Effects of WIC on cognitive development", *Am J Public Health*, vol. 73, no. 6, pp. 698-700.

Pollitt, E., Soemantri, A. G., Yunis, F., & Scrimshaw, N. S. 1985, "Cognitive effects of iron-deficiency anaemia", *Lancet*, vol. 1, no. 8421, p. 158.

Pollitt, E. & Mathews, R. 1998, "Breakfast and cognition: an integrative summary", *Am J Clin Nutr*, vol. 67, no. 4, pp. 804S-813S.

Pollitt, E., Cueto, S., & Jacoby, E. R. 1998, "Fasting and cognition in well- and undernourished schoolchildren: a review of three experimental studies", *Am J Clin Nutr*, vol. 67, no. 4, pp. 779S-784S.

Powell, C., Grantham-McGregor, S., & Elston, M. 1983, "An evaluation of giving the Jamaican government school meal to a class of children", *Hum Nutr Clin Nutr*, vol. 37, no. 5, pp. 381-388.

Preziosi P, Glan P, Deheeger M, Yacoub N, Drewnomwski A, & Hercberg S 1999, *Breakfast type, Daily nutrient Intakes and Vitamin and Mineral Status of French Children, Adolescents and Adults* 18.

Ragozzino, M. E. & Gold, P. E. 1991, "Glucose effects on mecamylamine-induced memory deficits and decreases in locomotor activity in mice", *Behav Neural Biol*, vol. 56, no. 3, pp. 271-282.

Ragozzino, M. E. & Gold, P. E. 1994, "Task-dependent effects of intra-amygdala morphine injections: attenuation by intra-amygdala glucose injections", *J Neurosci*, vol. 14, no. 12, pp. 7478-7485.

Reid, M. & Hammersley, R. 1994, "The effects of sucrose on everyday eating in normal weight men and women", *Appetite*, vol. 22, no. 3, pp. 221-231.

Resnicow K 1991, "Breakfast Matters: Benefits of breakfast to cognitive performance and health", *J School Health*, vol. 64, pp. 81-85.

Ricardson A.J & Puri B.K 2002, "A randomised double-blind, placebo-controlled study of the effects of suplmentattion with highly insaturated fatty acids on ADHD-related symptoms in children with specifuc learning difficulties", *Progress in Neuro-Psychopharmacology and Biological Psychiatry*, vol. 26, no. 2, pp. 233-239.

Ricardson R.A, Fearon K.C.H, Watson W, Hume R, & Shenkin A 1990, "Assessment of body composition by bioelectrical impedance compaed with anthropometry, total body potassium and tritiated water", *Proc Nutr Soc*, vol. 49:159A.

Ricny, J., Tucek, S., & Novakova, J. 1992, "Acetylcarnitine, carnitine and glucose diminish the effect of muscarinic antagonist quinuclidinyl benzilate on striatal acetylcholine content", *Brain Res*, vol. 576, no. 2, pp. 215-219.

Rogers, P. J. & Lloyd, H. M. 1994, "Nutrition and mental performance", *Proc Nutr Soc*, vol. 53, no. 2, pp. 443-456.

Rosenberg, I. H. & Miller, J. W. 1992, "Nutritional factors in physical and cognitive functions of elderly people", *Am J Clin Nutr*, vol. 55, no. 6 Suppl, pp. 1237S-1243S.

Ruxton, C. H., O'Sullivan, K. R., Kirk, T. R., Belton, N. R., & Holmes, M. A. 1996, "The contribution of breakfast to the diets of a sample of 136 primary- schoolchildren in Edinburgh", *Br J Nutr*, vol. 75, no. 3, pp. 419-431.

Sampson, A. E., Dixit S, & Meyers, A. F. 1995, "The Nutritional Impact of Breakfast Consumption on the Diets of Inner-city African-American Elementary School Children", *J Natl Med Assoc*, vol. 87, pp. 195-202.

Schlundt, D. G., Hill, J. O., Sbrocco, T., Pope-Cordle, J., & Sharp, T. 1992, "The role of breakfast in the treatment of obesity: a randomized clinical trial", *Am.J Clin Nutr*, vol. 55, no. 3, pp. 645-651.

Scholey, A. B., Harper, S., & Kennedy, D. O. 2001, "Cognitive demand and blood glucose", *Physiol Behav*, vol. 73, no. 4, pp. 585-592.

Schweiger, U., Laessle, R., Kittl, S., Dickhaut, B., Schweiger, M., & Pirke, K. M. 1986, "Macronutrient intake, plasma large neutral amino acids and mood during weight-reducing diets", *J Neural Transm.*, vol. 67, no. 1-2, pp. 77-86.

Scottish Executive 2001, *Nutrition in Schools: Scottish Nutrient Standards for School Lunches.*

Scottish Executive 2003, *Hungry For Success: A whole school approach to school meals in Scotland.*

Scottish Office 1993, *Scotland's Health - A Challenge to us all.*, Report of a Working Party to the Chief Medical Officer for Scotland. HMSO, Edinburgh.

Segal, K. R., Van Loan, M., Fitzgerald, P. I., Hodgdon, J. A., & Van Itallie, T. B. 1988, "Lean body mass estimation by bioelectrical impedance analysis: a four-site cross-validation study", *Am J Clin Nutr*, vol. 47, no. 1, pp. 7-14.

Selhub, J., Jacques, P. F., Wilson, P. W., Rush, D., & Rosenberg, I. H. 1993, "Vitamin status and intake as primary determinants of homocysteinemia in an elderly population", *JAMA*, vol. 270, no. 22, pp. 2693-2698.

Shaffer D.R 1985, *Developmental psychology, theory, research and application* Monterey, CA: Brooks/Cole Publishing.

Sieber, F. E. & Traystman, R. J. 1992, "Special issues: glucose and the brain", *Crit Care Med*, vol. 20, no. 1, pp. 104-114.

Siega-Riz A.M & Popkin B.M 1998, *The Effect of Ethnicity on the Benefits of Ready-to-eat Cereal Consumption at Breakfast* 3.

Siega-Riz, A. M., Popkin, B. M., & Carson, T. 1998, "Trends in breakfast consumption for children in the United States from 1965-1991", *Am J Clin Nutr*, vol. 67, no. 4, pp. 748S-756S.

Simeon, D. & Grantham-McGregor, S. 1987, "Cognitive function, undernutrition, and missed breakfast", *Lancet*, vol. 2, no. 8561, pp. 737-738.

Simeon, D. T. & Grantham-McGregor, S. 1989, "Effects of missing breakfast on the cognitive functions of school children of differing nutritional status", *Am J Clin Nutr.*, vol. 49, no. 4, pp. 646-653.

Simeon, D. T. & Grantham-McGregor, S. 1990, *Nutritional Deficiencies and Children's Behaviour and mental development* 3.

Simeon, D. T. 1998, "School feeding in Jamaica: a review of its evaluation", *Am J Clin Nutr*, vol. 67, no. 4, pp. 790S-794S.

Sims, R. E., Rushford, F. E., Huston, D. P., & Cunningham, G. R. 1987, "Successful immunosuppressive therapy in a patient with autoantibodies to insulin receptors and immune complex glomerulonephritis", *South Med J*, vol. 80, no. 7, pp. 903-906.

Slate, J. R. & Fawcett, J. 1996, "Gender differences in Wechsler performance scores of school-age children who are deaf or hard of hearing", *Am Ann Deaf*, vol. 141, no. 1, pp. 19-23.

Slaugher M.H, Lohman T.G, Boileau R.A, & Horswill C.A 1988, "Skinfold equations of body fatness and youth", *Hum Biol*, vol. 60, pp. 709-723.

Smith, A., Kendrick, A., Maben, A., & Salmon, J. 1994, "Effects of breakfast and caffeine on cognitive performance, mood and cardiovascular functioning", *Appetite*, vol. 22, no. 1, pp. 39-55.

Smith, A., Bazzoni, C., Beale, J., Elliott-Smith, J., & Tiley, M. 2001, "High fibre breakfast cereals reduce fatigue", *Appetite*, vol. 37, no. 3, pp. 249-250.

Smith, A. D. 1975, "Aging and interference with memory", *J Gerontol*, vol. 30, no. 3, pp. 319-325.

Smith, A. P. 1982, "The effects of noise and task priority on recall of order and location", *Acta Psychol*, vol. 51, no. 3, pp. 245-255.

Smith, A. P. & Broadbent, D. E. 1982, "The effects of noise on recall and recognition of instances of categories", *Acta Psychol*, vol. 51, no. 3, pp. 257-271.

Smith, A. P., Kendrick, A. M., & Maben, A. L. 1992, "Effects of breakfast and caffeine on performance and mood in the late morning and after lunch", *Neuropsychobiology*, vol. 26, no. 4, pp. 198-204.

Smith, D. N. 1993, "Bioelectrical impedance and body composition", *Lancet*, vol. 341, no. 8844, p. 569.

Smith, E. E. & Jonides, J. 1997, "Working memory: a view from neuroimaging", *Cognit Psychol*, vol. 33, no. 1, pp. 5-42.

Smithers G., Gregory J., Coward W.A., Wright A., Elsom R., & Wenlock R. 1998, "British National Diet and Nutrition Survey of young people aged 4-18 years: feasibility of the dietary assessment methodology.", *Abstracts of the Third International conference on Dietary Assessment Methods Eur J Clin Nutr* p. S2. S76.

Sokoloff, L. 1976, "[1-14C]-2-deoxy-d-glucose method for measuring local cerebral glucose utilization. Mathematical analysis and determination of the

"lumped" constants", *Neurosci Res Program Bull*, vol. 14, no. 4, pp. 466-468.

Sommerville J & O'Reagan M 1993, "The Contribution of breakfast to micronutrient adequacy of the Irish Diet", *Journal of Nutrition and Dietetics*, vol. 6, pp. 223-228.

Speckerelle Y, Herbeth B, & Deschamps J.P 1992, "Dietary Behaviour ofan adolescent French male population", *J Hum Nutr Diet*, vol. 5, pp. 161-168.

Squire, L. R. 1987, "The organization and neural substrates of human memory", *Int J Neurol*, vol. 21-22, pp. 218-222.

Stone, G. & Sadowski, I. 1993, "GAL4 is regulated by a glucose-responsive functional domain", *EMBO J*, vol. 12, no. 4, pp. 1375-1385.

Street C, Chan W, Grantham-McGregor, S., Ani C, Walker M, Dowler E, & Brown J.L 1999, *Fit for School: How breakfast Clubs Meet Health, Education and Childcare Needs*, New Policy Institute.

Street C & Kenway K 1999, *Food For Thought: breakfast clubs and their challenges*, New Policy Institute.

Summers, W. K., Majovski, L. V., Marsh, G. M., Tachiki, K., & Kling, A. 1986, "Oral tetrahydroaminoacridine in long-term treatment of senile dementia, Alzheimer type", *N Engl J Med*, vol. 315, no. 20, pp. 1241-1245.

Talley, J. L. 1986, "Memory in learning disabled children: digit span and the Rey Auditory Verbal Learning Test", *Arch Clin Neuropsychol*, vol. 1, no. 4, pp. 315-322.

Tanner, J. M., Whitehouse, R. H., & Takaishi, M. 1966, "Standards from birth to maturity for height, weight, height velocity, and weight velocity: British children, 1965. I", *Arch Dis Child*, vol. 41, no. 219, pp. 454-471.

Tanner, J. M., Whitehouse, R. H., & Takaishi, M. 1966, "Standards from birth to maturity for height, weight, height velocity, and weight velocity: British children, 1965. II", *Arch Dis Child*, vol. 41, no. 220, pp. 613-635.

Tanner, J. M. 1986, "Normal growth and techniques of growth assessment", *Clin Endocrinol Metab*, vol. 15, no. 3, pp. 411-451.

Taylor and Nelson 2004, *Family Food Panel, Kellogg's*.

The Scottish Diet Action Plan 1997, *Improving Nutrition in Scottish School Children*.

Todd, K. S., Hudes, M., & Calloway, D. H. 1983, "Food intake measurement: problems and approaches", *Am J Clin Nutr*, vol. 37, no. 1, pp. 139-146.

Touliatos, J. & Lindholm, B. W. 1975, "Relationships of children's grade in school, sex, and social class to teachers' ratings on the behavior problem checklist", *J Abnorm Child Psychol*, vol. 3, no. 2, pp. 115-126.

Traub, S. L. & Kichen, L. 1983, "Estimating ideal body mass in children", *Am J Hosp Pharm*, vol. 40, no. 1, pp. 107-110.

Tremblay, M. S. & Willms, J. D. 2000, "Secular trends in the body mass index of Canadian children", *CMAJ.*, vol. 163, no. 11, pp. 1429-1433.

Tucek, S. 1983, "Acetylcoenzyme A and the synthesis of acetylcholine in neurones: review of recent progress", *Gen Physiol Biophys*, vol. 2, no. 4, pp. 313-324.

University of East Anglia 2000, *The National Evaluation of School Breakfast Clubs*.

Vaisman N, Voet H, Akivis A, & Vakil E 2002, "Effect of Breakfast timing on the Cognitive Functions of Elementary School Students", *Education*, vol. 6, no. 14, pp. 1089-1092.

Van Horn, L. V., Gernhofer, N., Moag-Stahlberg, A., Farris, R., Hartmuller, G., Lasser, V. I., Stumbo, P., Craddick, S., & Ballew, C. 1990, "Dietary assessment in children using electronic methods: telephones and tape recorders", *J Am Diet Assoc*, vol. 90, no. 3, pp. 412-416.

Vanhanen, M., Kuusisto, J., Koivisto, K., Mykkanen, L., Helkala, E. L., Hanninen, T., Riekkinen, P., Sr., Soininen, H., & Laakso, M. 1999, "Type-2 diabetes and cognitive function in a non-demented population", *Acta Neurol Scand*, vol. 100, no. 2, pp. 97-101.

Walker , J. & Kindlen , S. 1998, "The effect of practice n the measurements of skinfold thickness by an inexperienced observer", *Proc Nutr Soc*, vol. 47:142A.

Walker, M., Rodham, D., Fulcher, G. R., Clayton, B., Farrer, M., & Alberti, K. G. 1993, "Bioelectrical impedance and body composition", *Lancet*, vol. 341, no. 8842, p. 448.

Wechsler D 1991, *Weschsler Intelligence Scale for Children- Third Edition UK* Capstone, London.

Weinberg, J., Diller, L., Gerstman, L., & Schulman, P. 1972, "Digit span in right and left hemiplegics", *J Clin Psychol*, vol. 28, no. 3, p. 361.

Wells, A. S., Read, N. W., & Craig, A. 1995, "Influences of dietary and intraduodenal lipid on alertness, mood, and sustained concentration", *Br J Nutr*, vol. 74, no. 1, pp. 115-123.

Wells, A. S. & Read, N. W. 1996, "Influences of fat, energy, and time of day on mood and performance", *Physiol Behav*, vol. 59, no. 6, pp. 1069-1076.

Wells, A. S., Read, N. W., Uvnas-Moberg, K., & Alster, P. 1997, "Influences of fat and carbohydrate on postprandial sleepiness, mood, and hormones", *Physiol Behav*, vol. 61, no. 5, pp. 679-686.

Wenk, G. L. 1989, "An hypothesis on the role of glucose in the mechanism of action of cognitive enhancers", *Psychopharmacology* , vol. 99, no. 4, pp. 431-438.

Werry, J. S. & Quay, H. C. 1971, "The prevalence of behavior symptoms in younger elementary school children", *Am J Orthopsychiatry*, vol. 41, no. 1, pp. 136-143.

Wesnes, K. A., Pincock, C., Richardson, D., Helm, G., & Hails, S. 2003, "Breakfast reduces declines in attention and memory over the morning in schoolchildren", *Appetite*, vol. 41, no. 3, pp. 329-331.

Widom, B. & Simonson, D. C. 1990, "Glycemic control and neuropsychologic function during hypoglycemia in patients with insulin-dependent diabetes mellitus", *Ann Intern Med*, vol. 112, no. 12, pp. 904-912.

Wong, K. L. & Tyce, G. M. 1983, "Glucose and amino acid metabolism in rat brain during sustained hypoglycemia", *Neurochem Res*, vol. 8, no. 4, pp. 401-415.

World Health Organisation 1985, *Estimates of Energy and Protein Requirements of Adults and Children.*

World Health Organisation 1990, *Life Course perspectives on coronary heart disease, stroke and diabetes. The evidence and implications for policy and research.*

World Health Organisation 1990, *Recommendation in Diet and Nutrition and the Prevention of Chronic Disease.*

World Health Organisation 1994, *Report on Infant and Young Child Nutrition Global Problems and Promising Development.*

World Health Organisation 2003, *Expert Report on Diet, Nutrition and Prevention of Chronic Diseases.*

Worobey H.S & Worobey J 1999, "Efficacy of a preschool breakfast program in reducing refined sugar intake", *International Journal Of Food Sciences and Nutrition*, vol. 50, pp. 391-397.

Worobey J and H.S 1999, "The impact of a 2 year school breakfast program for pre-school aged children on their nutrient intake and pre-academic performance", *Child Study Journal*, vol. 29, no. 2, pp. 113-131.

Wrieden, W. L. & Moore, E. J. 1995, "The dietary habits of 11-12 year-old children in two Tayside secondary schools--comparison with the targets set by the Scottish Diet Report", *Health Bull*, vol. 53, no. 5, pp. 299-306.

Wrieden, W. L. & Moore, E. J. 2001, "Food and Nutrient Content of Meals chosen by secnadry school pupils under 2 different types of school meals provision", *Proc Nutr Soc*. vol. 44, no 3, pp 345-347

Wu, Y. T., Nielsen, D. H., Cassady, S. L., Cook, J. S., Janz, K. F., & Hansen, J. R. 1993, "Cross-validation of bioelectrical impedance analysis of body composition in children and adolescents", *Phys Ther*, vol. 73, no. 5, pp. 320-328.

Wurtman, R. J. & Fernstrom, J. D. 1974, "Control of brain serotonin by the diet", *Adv.Neurol.*, vol. 5, pp. 19-29.

Wurtman, R. J. 1981, "The effects of nutritional factors on memory", *Acta Neurol.Scand Suppl*, vol. 89, pp. 145-154.

Wyon, D. P., Abrahamsson, L., Jartelius, M., & Fletcher, R. J. 1997, "An experimental study of the effects of energy intake at breakfast on the test performance of 10-year-old children in school", *Int J Food Sci Nutr*, vol. 48, no. 1, pp. 5-12.

Zabik M.E 1987, "Impact of ready-to-eat cereal consumption on nutrient intake", *Cereal Foods World*, vol. 32, pp. 234-239.

Annals of Nutrition and Metabolism, Abstracts 2003:47 pg 580

BREAKFAST AND COGNITION. S Mehrotra, M Clapham, I Davidson, V Chisholm, *Queen Margaret University College, Clerwood Terrace, Corstorphine, Edinburgh, EH12 8TS, UK.*

Breakfast clubs have been introduced in the UK in an attempt to improve the diets of school children . The aim of this research was to determine the effect of a breakfast club breakfast (BC) compared to a breakfast served at home (HB) on nutritional intake and cognition of Scottish primary school children.

Breakfast Clubs serving a choice of cooked breakfasts and/or toast or cereal were available to the BC group at school. Dietary information and Digit Span, Coding and Arithmetic subsets from the Wechsler Intelligence Scale for Children ($WISC\text{-}III^{uk}$) were collected at baseline before the commencement of the breakfast club, and 3 time points at 9-week intervals post intervention.

There were more cooked breakfasts consumed by the BC ($p \leq 0.01$) group and greater amounts of cereal eaten by the HB group ($p \leq 0.001$). Percentage energy from fat, polyunsaturated and monounsaturated fat was higher in the BC group as compared to the HB group at collections 3 and 4 ($p \leq 0.05$–0.001). In the HB group percentage energy from carbohydrate and starch was greater at collections 2, 3 ($p \leq 0.01$) and 4 ($p = 0.05$-0.06). There were pronounced improvements in the HB group in all $WISC\text{-}III^{uk}$ subsets when baseline results were compared to scores at collection 3 and 4 ($p \leq 0.001$). A positive correlation was found between Coding and percentage energy from sugars and carbohydrate ($p \leq 0.01$) at data collection 3 and 4 in both groups. A positive correlation between Coding and starch existed in the HB group at data collection 4 ($p \leq 0.05$). Digit Span and glucose were positively correlated ($p \leq 0.05$) in the HB group at data collection 3.

These findings suggest that a breakfast higher in percentage energy from carbohydrate might benefit short-term memory and contribute to academic performance in school children.